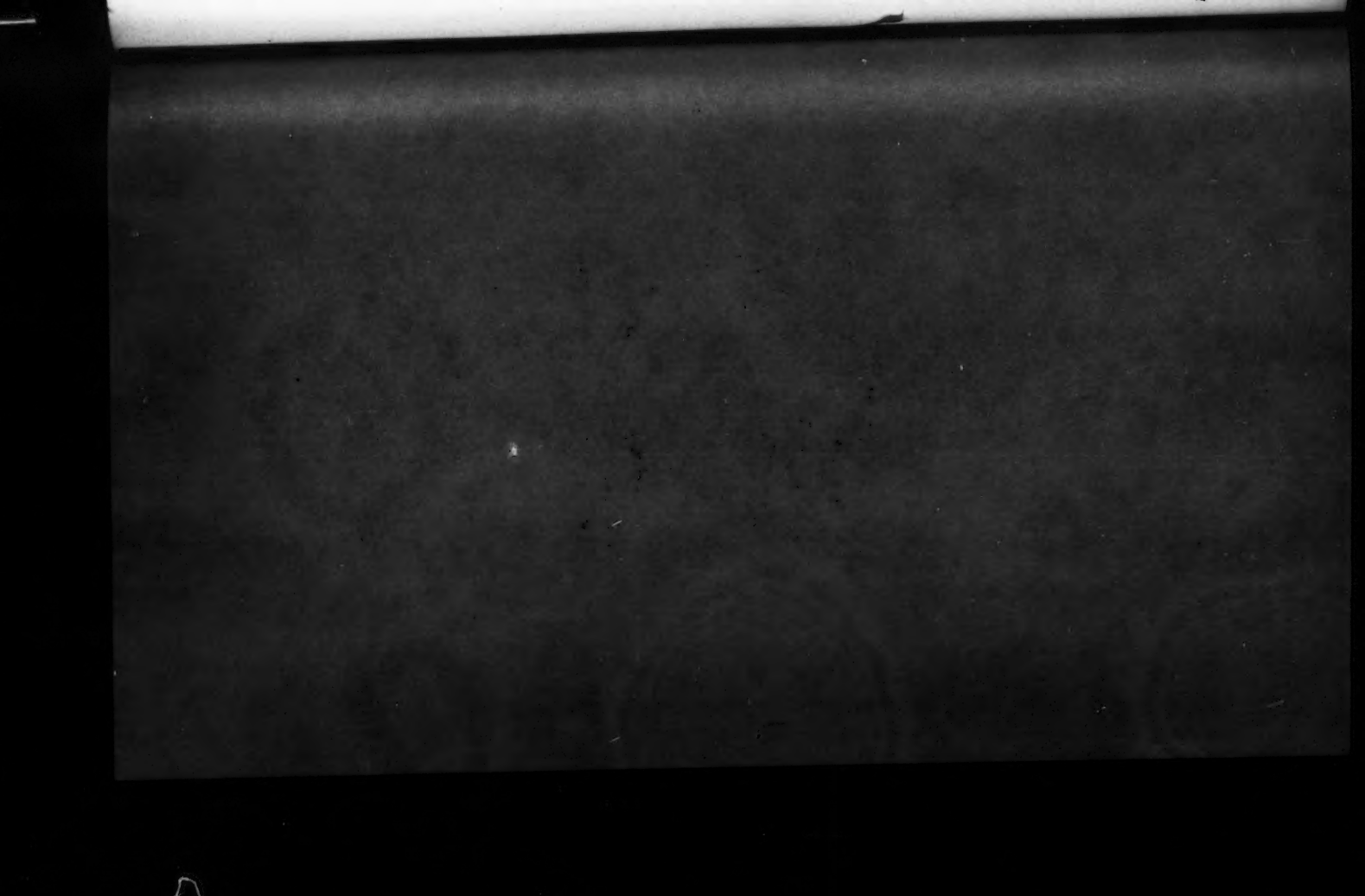
TRANSACTIONS

OF THE

AMERICAN FISHERIES SOCIETY

SIXTY-SECOND ANNUAL MEETING
BALTIMORE, MARYLAND
SEPTEMBER 21, 22 and 23, 1932



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OF THE

American Fisheries Society

SIXTY-SECOND ANNUAL MEETING
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September 21, 22 and 23, 1932

Published Annually by the Society

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THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fisheries problems.

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*Died January 26, 1932. Succeeded by Eben W. Cobb, Hartford, Conn., as Acting Librarian.

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PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1. William Clift	1870-1872	New York, N. Y.
2. William Clift	1872-1873	Albany, N. Y.
3. William Clift	1873-1874	New York, N. Y.
4. Robert B. Roosevelt	1874-1875	New York, N. Y.
5. Robert B. Roosevelt	1875-1876	New York, N. Y.
6. Robert B. Roosevelt	1876-1877*	New York, N. Y.
7. Robert B. Roosevelt	1877-1878	New York, N. Y.
8. Robert B. Roosevelt	1878-1879	New York, N. Y.
9. Robert B. Roosevelt	1879-1880	New York, N. Y.
10. Robert B. Roosevelt	1880-1881	New York, N. Y.
11. Robert B. Roosevelt	1881-1882	New York, N. Y.
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13. James Benkard	1883-1884	New York, N. Y.
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16. W. M. Hudson	1886-1887	Chicago, Ill.
17. William L. May	1887-1888	Washington, D. C.
18. John Bissell	1888-1889	Detroit, Mich.
19. Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20. Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21. James A. Henshall	1891-1892	Washington, D. C.
22. Herschel Whitaker	1892-1893	New York, N. Y.
23. Henry C. Ford	1893-1894	Chicago, Ill.
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26. Herschel Whitaker	1896-1897	New York, N. Y.
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32. George M. Bowers	1902-1903	Put-in-Bay, Ohio
33. Frank N. Clark	1903-1904	Woods Hole, Mass.
34. Henry T. Root	1904-1905	Atlantic City, N. J.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

35. C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.
36. E. A. Birge	1906-1907	Grand Rapids, Mich.
37. Hugh M. Smith	1907-1908	Erie, Pa.
38. Tarleton H. Bean	1908-1909	Washington, D. C.
39. Seymour Bower	1909-1910	Toledo, Ohio
40. William E. Meehan	1910-1911	New York, N. Y.
41. S. F. Fullerton	1911-1912	St. Louis, Mo.
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43. Henry B. Ward	1913-1914	Boston, Mass.
44. Daniel B. Fearing	1914-1915	Washington, D. C.
45. Jacob Reighard	1915-1916	San Francisco, Calif.
46. George W. Field	1916-1917	New Orleans, La.
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48. M. L. Alexander	1918-1919	New York, N. Y.
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50. Nathan R. Buller	1920-1921	Ottawa, Canada
51. William E. Barber	1921-1922	Allentown, Pa.
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53. George C. Embody	1923-1924	St. Louis, Mo.
54. Eben W. Cobb	1924-1925	Quebec, Canada
55. Charles O. Hayford	1925-1926	Denver, Colo.
56. John W. Titcomb	1926-1927	Mobile, Ala.
57. Emmeline Moore	1927-1928	Hartford, Conn.
58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Canada
61. James A. Rodd	1931-1932	Hot Springs, Arkansas
62. H. S. Davis	1932-1933	Baltimore, Md.

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PART I
BUSINESS SESSIONS

TRANSACTIONS

OF THE

AMERICAN FISHERIES SOCIETY

AT

BALTIMORE, MARYLAND

September 21, 22 and 23, 1932

The Sixty-second Annual Meeting of the American Fisheries Society was held at The Lord Baltimore Hotel, Baltimore, Maryland, September 21, 22 and 23, 1932.

REGISTERED ATTENDANCE

The following is the list of registered members, delegates and guests in attendance:

Adams, William C., Chief Division of Fish and Game, Albany, N. Y.
Agersborg, Dr. H. P. K., Dept. of Fisheries and Game, Concord, N. H.
Allen, A. G., Oakdale, N. Y.
Amsler, Guy, Secy. Game and Fish Com., Little Rock, Ark.
Armstrong, Richard, Sea Food Commissioner, Newport News, Va.
Atkinson, N. J., Biologist, Lucerne-in-Quebec Community Assn., Montreal, Canada.
Babylon, George R., Baltimore, Md.
Bachrach, David, Baltimore, Md.
Ball, John N., American Game Association, Madison, Wis.
Barber, Frederick S., Mt. Victoria, Md.
Barrett, Paul A., Port Deposit, Md.
Bedsworth, Wade H., Salisbury, Md.
Bell, Dr. W. B., U. S. Bureau of Biological Survey, Washington, D. C.
Berg, George, Indiana Conservation Dept., Indianapolis, Ind.
Birdseye, Clarence, General Foods Corp., Gloucester, Mass.
Birsch, William L., Elizabeth City, N. C.
Blogg, Percy T., Baltimore, Md.
Bode, I. T., Fish and Game Commission, Des Moines, Iowa.
Bode, Mrs. I. T., Des Moines, Iowa.
Boring, E. M., Mobile, Ala.
Bower, Ward T., U. S. Bureau of Fisheries, Washington, D. C.
Branchaud, Louis A., Washington, D. C.
Brown, James, Fish and Game Commissioner, Montpelier, Vt.
Browning, Richard S., Oakland, Md.
Buller, N. R., Former Pennsylvania Fish Commissioner, Harrisburg, Pa.
Bump, Gardiner, Supt. Bureau of Game, Conservation Dept., Albany, N. Y.
Buntin, Howell, State Game and Fish Warden, Nashville, Tenn.
Burlington, H. J., Pres. Board of Game Commissioners, Montvale, N. J.
Burroughs, P. E., Salisbury, Md.
Callaghan, F. P., Washington, D. C.
Carey, Raymond M., Princess Anne, Md.
Chambliss, Pete, Baltimore, Md.
Chute, W. H., Director, John G. Shedd Aquarium, Grant Park, Chicago, Ill.
Clark, Arthur L., Supt. State Bd. of Fisheries and Game, Hartford, Conn.
Clark, T. E., Relay, Md.
Cobb, Eben W., Chief, Division of Fish Restoration, Hartford, Conn.
Cook, A. B., Jr., Field Supt. of Hatcheries, Michigan Conservation Dept., Iona, Mich.
Cook, Mrs. A. B., Jr., Iona, Mich.
Cooper, R., Balto. Laboratories, Wilmington, Calif.
Corcoran, J. P., Centreville, Md.
Cowden, S. M., Conservation Dept., Albany, N. Y.
Crampton, Albert, Hagerstown, Md.
Culler, C. F., U. S. Bureau of Fisheries, La Crosse, Wis.
Dallam, Richard, Belair, Md.
Dauenhauer, J. B., Jr., Dept. of Conservation, New Orleans, La.
Davis, Dr. H. S., U. S. Bureau of Fisheries, Washington, D. C.
Day, Robert E., Sykesville, Md.
Denmead, Talbott, Law Enforcement Officer, U. S. Bureau of Fisheries, Washington, D. C.
Diffendahl, J. Lloyd, Westminster, Md.
Dinsmore, A. H., U. S. Bureau of Fisheries, St. Johnsbury, Vt.
Doetz, Carl, Utica, N. Y.
Earle, Swepson, Commissioner, Conservation Dept., Baltimore, Md.
Earnshaw, Frank L., U. S. Biological Survey, Washington, D. C.
Edwards, Nelson, Baltimore, Md.

Embody, Dr. George C., Cornell University, Ithaca, N. Y.
England, C. H., State Game Warden, Dept. of Conservation and Development, Raleigh, N. C.
Englar, Mrs. David F., Jr., Baltimore, Md.
Ewald, William G., Baltimore, Md.
Fearnow, Theodore C., Supt. State Fish Hatcheries, Charleston, W. Va.
Fearnow, E. C., U. S. Bureau of Fisheries, Washington, D. C.
Fiedler, R. H., U. S. Bureau of Fisheries, Washington, D. C.
Field, Dr. George W., Washington, D. C.
Fish, Dr. Frederick F., U. S. Bureau of Fisheries, Washington, D. C.
Follett, Richard E., Secy., Detroit Zoological Society, Detroit, Mich.
Foran, Col. Arthur F., Vice-Pres., More Game Birds in America, New York, N. Y.
Foster, C. S., Chief Game and Fish Warden, Dover, Del.
Goodide, Samuel P., Commission of Game and Inland Fisheries, Afton, Va.
Gordon, Seth, Pres., American Game Assn.; Secy. American Fisheries Society, Washington, D. C.
Gordon, Mrs. Seth, Washington, D. C.
Gowanloch, James N., Biologist, Bureau of Research, Dept. of Conservation, New Orleans, La.
Greeley, Dr. John R., Museum of Zoology, Ann Arbor, Mich.
Greene, Dr. C. Willard, Conservation Dept., Albany, N. Y.
Greer, M. C., Baltimore, Md.
Grim, D. N., Blooming Grove Club, Glen Eyre, Pa.
Gustafson, R. O., Washington, D. C.
Hamerstrom, F., Jr., Boston, Mass.
Hamerstrom, Mrs. F., Jr., Boston, Mass,
Hamilton, R. L., Elk Ridge, Md.
Hampe, Frank, Houston, Tex.
Harrelson, J. W., Director Dept. of Conservation and Development, Raleigh, N. C.
Harrison, E. L., American Game Association, Washington, D. C.
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Herbert, William F., St. Marys, Md.
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Hill, Charles E., Snow Hill, Md.
Hoffman, F. A., Havre de Grace, Md.
Hogarth, George R., Director, Dept. of Conservation, Lansing, Mich.
Hoofnagle, G. W., U. S. Bureau of Fisheries, Orangeburg, S. C.
Horst, Louis, Sunderland, Mass.
Howley, Thomas, New York, N. Y.
Hunter, R. M., Nicholasville, Ky.
James, C. C., Supt. State Fish Hatcheries, Summerville, Ga.
James, M. C., U. S. Bureau of Fisheries, Washington, D. C.
Johnson, H. H., Baltimore, Md.
Keil, William M., Tuxedo Park, N. Y.
Kelsey, J. V., Daytona Beach, Fla.
Kenney, Harry, Cumberland, Md.
Kenney, Raymond J., Director Division of Fisheries and Game, Boston, Mass.
Kingsbury, Oliver R., Ithaca, N. Y.
Kinnear, Karl, Pres. Fishing Tackle Manufacturers' Institute, Geneva, Ohio.
Kirby, G. M., Jefferson City, Mo.
Kolmer, Harold S., Secy. Conservation Dept., Baltimore, Md.
Kreager, Paul T., St. Marks, Fla.
Laird, James A., South Side Sportsmen's Club of L. I., Oakdale, N. Y.
Langlois, T. H., Bureau of Fish Propagation, Div. of Conservation, Columbus, Ohio.
Leach, Glen C., U. S. Bureau of Fisheries, Washington, D. C.
LeCompte, E. Lee, State Game Warden, Conservation Dept., Baltimore, Md.
Lloyd, Hoyes, Supervisor of Wildlife, National Parks of Canada, Ottawa, Canada.
Locke, S. B., Conservation Director Izaak Walton League of America, Chicago, Ill.
Loewith, Julius, New York, N. Y.
Lord, R. F., Pittsford, Vt.
McCallister, J. G., Baltimore, Md.
McCullough, E. R., Hancock, Md.
McGavock, A. M., Hackettstown, N. J.
McMurtrey, M. S., Warden, Fish and Game Commission, Oklahoma City, Okla.
Maccubbin, H. B., Pres. Baltimore Chapter, Izaak Walton League, Baltimore, Md.
MacSpiden, T. J., Baltimore, Md.
Magee, Dr. M. D'Arcy, Vice-Pres. Izaak Walton League of America, Washington, D. C.
Markus, Henry C., U. S. Bureau of Fisheries, Rochester, N. Y.
Maurek, Burnie, Game and Fish Commissioner, Bismarck, N. D.
Miles, Hon. Lee, Chairman Game and Fish Commission, Little Rock, Ark.
Miller, Ralph W., Accident, Md.
Minke, Joseph A., Cumberland, Md.
Mitchell, John L., Stemmers Run, Md.
Mitten, J. Albert, Westminster, Md.
Moehlman, Henry J., Baltimore, Md.
Montgomery, George M., East Orland, Maine.
Montgomery, Van H., Bartlesville, Okla.
Moore, Dr. Emmeline, Conservation Dept., Albany, N. Y.
Moore, Dr. William H., Bd. of Game Commissioners, Philadelphia, Pa.
Muller, Adolph, Pres. Bd. of Game Commissioners, Norristown, Pa.
Neelly, Harry, Game and Fish Commissioner, Searcy, Ark.
Nolting, Carl, Commission of Inland Game and Fisheries, Trevilians, Va.
Norris, Richard T., Baltimore, Md.
Noyes, Haskell, Chairman Conservation Commission, Milwaukee, Wis.
Oberholser, Harry C., U. S. Biological Survey, Washington, D. C.
Odell, T. T., Hobart College, Geneva, N. Y.
O'Malley, Henry, Commissioner U. S. Bureau of Fisheries, Washington, D. C.
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Otterson, John H., E. I. duPont de Nemours & Co., Wilmington, Del.
Palmer, C. M., Jr., American Game Association, Washington, D. C.

Palmer, Lee D., Belair, Md.
Palmer, Dr. T. S., U. S. Biological Survey, Washington, D. C.
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Pfeiffer, Karl E., Baltimore, Md.
Phebus, Benjamin F., Frederick, Md.
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Powell, Alton, Baltimore, Md.
Powell, A. J., Philadelphia, Pa.
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Radcliffe, Dr. Lewis, Deputy Commissioner U. S. Bureau of Fisheries, Washington, D. C.
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Regan, C. C., Kentucky Game and Fish Commission, Covington, Ky.
Reid, Kenneth A., Pennsylvania Fish Commission, Connellsville, Pa.
Reinhart, William H., Commissioner Division of Conservation, Columbus, Ohio.
Robertson, R. W., Baltimore, Md.
Rodd, J. A., Dept. of Fisheries, Ottawa, Canada.
Rodd, Mrs. J. A., Ottawa, Canada.
Rogers, James W., Hyattsville, Md.
Rogers, Mrs. James W., Hyattsville, Md.
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Shirts, Walter, Supt. Division of Fish and Game, Indianapolis, Ind.
Shoemaker, Carl D., Secy. U. S. Senate Committee on Wild Life Resources, Washington, D. C.
Silberman, J. D., Chicago, Ill.
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Smith, G. Tyler, Baltimore, Md.
Stadlmeir, Albert, Pleasantville, N. J.
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Stewart, William D., Commissioner of Game and Fish, St. Paul, Minn.
Stieff, Frederick P., Baltimore, Md.
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Surber, Thaddeus, State Game and Fish Dept., St. Paul, Minn.
Taylor, B. W., Director of Fish Culture, Dept. of Colonization, Game and Fisheries, Quebec, Canada.
Thompson, E. P., Hartsville, Mass.
Tolson, John H., Stevensville, Md.
Tomeraasen, G. A., Chicago, Ill.
Towner, Merle E., Pres. Maryland State Game and Fish Protection Assn., Baltimore, Md.
Trautman, Milton B., Div. of Conservation, Columbus, Ohio.
Tresselt, Frederick, Thurmont, Md.
Trimbley, Gordon L., Ithaca, N. Y.
Truitt, Dr. R. V., Director Chesapeake Biological Laboratory, Solomons Island, Md.
Tucker, George, Gilmer, Tex.
Tucker, William J., Ex-Secy. Game, Fish and Oyster Commission, Austin, Tex.
Turner, Russell C., Anne Arundel, Md.
Twitty, Peter J., Game and Fish Commissioner, Atlanta, Ga.
Van Oosten, Dr. John, U. S. Bureau of Fisheries, University Museums, Ann Arbor, Mich.
Van Huizen, Peter J., Cambridge, Md.
Waddell, H. M., Glenwood, Md.
Walker, Talbott, Baltimore, Md.
Waller, Maj. L. W. T., Jr., Meadowbrook, Pa.
Walter, George M., Talbot, Md.
Walters, W. Carroll, Germantown, Md.
Watson, E. J., Chestertown, Md.
Webster, B. O., Conservation Commission, Madison, Wis.
Weems, Thos. I., Stockley, Md.
West, H. F., McClellansville, S. C.
Westerman, Fred A., Dept. of Conservation, Lansing, Mich.
White, E. F. G., American Game Association, Ottawa, Canada.
Whitehead, E. B., Savannah, Ga.
Wickliff, E. L., Conservation Division, Columbus, Ohio.
Wilmer, Bruce M., Pope's Creek, Md.
Wolf, Louis E., Cornell University, Ithaca, N. Y.
Woodward, C. C., Commissioner, Dept. of Game and Freshwater Fish, Tallahassee, Fla.
Young, E. C., Ottawa, Canada.

BUSINESS SESSIONS

The meeting was called to order by President J. A. Rodd at 9:15 A. M. Wednesday, September 21, 1932, aboard the Steamer Latrobe en route from Baltimore to Annapolis.

The address of welcome was delivered by Mr. E. Lee LeCompte, State Game Warden of Maryland. Acknowledgment of this address of welcome was made by the President.

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

For the year 1931-32

SETH GORDON

The American Fisheries Society is one of the few organizations that has come through a very trying period in remarkably good condition, financially and otherwise.

While the Society had thirty-one resignations during the year ending September 1, when the books were closed, and was compelled to drop one hundred and seven members for non-payment of dues, there were sixty new members received during the year. There were seven deaths of which your Secretary-Treasurer received notice. This leaves a net loss of eighty-five members.

At first blush this looks rather large out of a membership of something under seven hundred, but it must be borne in mind that during the period covered by the last annual report no members had been dropped for non-payment of dues, even though a number were then subject to such action.

Before dropping members from the rolls a special letter was written to each calling attention to the provision in the By-Laws, and urging that they remit back dues. Those who did not reply were then dropped.

There was no special campaign for new members, other than to urge the members to enroll their acquaintances when official notices for this meeting were mailed out. The response was quite encouraging, and since September 1 when the books were closed a number of additional applications for regular membership and one application for life membership were received.

In my opinion the members of the Society are really doing themselves an injustice by failing to bring to the attention of their co-workers and friends the desirability of membership in the Society. Every state employee engaged in fish work, particularly the superintendents of hatcheries, supervisors of commercial fisheries, and others, ought to be a member of this Society and receive the annual Transactions.

In one state I am thinking of it has been the practice for the state department to pay the annual dues of the superintendents of their hatcheries in order that the Transactions may become the permanent property of each hatchery in the state rather than the property of the individual. When there is a change of superintendents all the Transactions are there for the use of the next man who comes along. Personally I think that is the best way to handle it; otherwise the employees themselves might not take sufficient interest to pay for the annual membership.

We also need more state departments as members; and we need more of the clubs that are interested in fisheries problems.

The new membership-year plan has worked out very nicely. It has eliminated much of the confusion of former years. Now when a member pays his dues he knows that the year will expire the 30th day of June next,

regardless of the date of the Annual Meeting or the actual publication date of the Transactions.

The Society suffered a terrific blow in the death of Jonh W. Titcomb, for many years one of the mainstays of the Society, and for some years its efficient Librarian. Mr. Titcomb's sudden passing created a very difficult situation in connection with the printing of the 1931 Annual Transactions because he was the Chairman of the Committee on Publications and had immediate charge of the production of the Transactions.

Your Secretary-Treasurer then took over the task and finally succeeded in getting the Transactions into print, although at a much later date than anticipated because of the delays in the office of the printer. However, Mr. Titcomb had made the arrangement for this printing and the only fair thing to do was to proceed as best we could.

Since the death of Mr. Titcomb, his co-worker, Mr. Eben W. Cobb, has continued to look after the work of the Librarian in a very able manner. Unfortunately, Mr. Cobb does not seem to be willing to continue in the capacity of Librarian, and it will be necessary either to persuade him to continue or to make some other arrangement.

Economies have been instituted wherever possible in handling the Society's affairs. While the total receipts for the year as compared with the previous year show a loss of approximately $675.00, the balance on hand September 1, 1932, is larger by approximately $700.00.

The additional funds on hand are due to earlier payments of membership dues for the current year than usual. Further to reduce confusion, it is recommended that the books of the Society be closed as of June 30 each year, and that a supplemental statement be made by the Secretary-Treasurer at the time of the Annual Meeting so that the members may be acquainted with the complete status of the Society's finances at that time.

An additional investment for the Permanent Fund was made during the year by using $525.00 from the savings account of the Permanent Fund and adding to it $159.25 from the General Fund. Your Secretary-Treasurer recommends that $1,000.00 additional be transferred from the General Fund and that this sum be invested in guaranteed first mortgage certificates of the kind which the Society already holds.

The financial transactions of the Society for the year ending September 1, 1932, were as follows:

TREASURER'S REPORT

General Fund

Receipts		
Balance on hand September 12, 1931		$1,279.59
Annual Dues:		
Individuals and Libraries		
For the year 1928	$9.00	
1929	12.00	
1930	63.00	
1931-1932	635.30	
1932-1933	663.00	
1933-1934	3.00	1,385.30

Clubs and Dealers			
For the year 1929	5.00		
1930	10.00		
1931-1932	40.00		
1932-1933	69.88		124.88
State Memberships			
For the year 1930	30.00		
1931-1932	170.00		
1932-1933	130.00		330.00
Sale of Transactions		$110.40	
Sale of Index-Catalogue		37.00	
Sale of Separates for the year 1930		107.78	
Returned Checks Redeposited			
J. D. Reid	3.00		
Spencer Otis	3.00	6.00	
Exchange on Checks		3.53	264.71
Total Receipts			$3,384.48
DISBURSEMENTS			
Printing and Stationery		$55.90	
Postage			
Secretary's Office	$82.30		
Librarian's Office	10.00	92.30	
Telegraph		2.81	
Office Supplies		3.75	
Premium on Treasurer's Bond		5.00	
Express		10.02	
Clerical Assistance, Sept., 1931-Sept., 1932		150.00	
Exchange on Checks		11.16	
Tax on Checks		.12	
Traveling Expenses—Seth Gordon		6.95	
Floral Tribute to E. T. D. Chambers		11.35	
Rental Safe Deposit Box		5.50	
Carfare		.15	
Transfer to Permanent Fund for Investment		159.25	
Refund on Membership		.50	
Check Returned		3.00	
Reporting 1931 Proceedings, Hot Springs Meeting		250.00	
Allowance for Additional Secretarial Expenses			
1930-1931		100.00	
1931-1932		100.00	
Transactions, 1931, Vol. 61			
Printing	712.55		
Proofreading Assistance	7.45		
Indexing	54.84	774.84	
Total Disbursements			$1,742.60
Receipts—General Fund		$3,384.48	
Disbursements—General Fund		1,742.60	
Balance on hand September 1, 1932			$1,641.88

Permanent Fund

Receipts		
Balance on hand September 12, 1932		$434.71
Interest on Savings Account	$4.78	
Interest on N. Y. Title Guarantee & Trust Co. Certificates	220.00	
Dividend on Commonweath & Southern pfd.	30.00	254.78
		$689.49
Disbursements		
10 Shares Commonwealth & Southern pfd. (Balance of cost on March 2, 1932, at 68¼, amounting to $159.25, was paid from the General Fund)		525.00
Balance on hand September 1, 1932		$164.49
Value of Certificates N. Y. Title Guarantee & Trust Co.		$4,000.00
Value of 10 shares Commonwealth & Southern pfd. par $100, as of September 1, 1932		650.00
Total Permanent Fund		$4,814.49

The report of the Secretary-Treasurer was received and referred to the Auditing Committee. Upon the approval of the committee it was later accepted by the Society.

REPORT OF ACTING LIBRARIAN

Eben W. Cobb

For several years Mr. Titcomb has acted as Librarian. It has involved a considerable amount of writing and also much work in caring for and mailing out volumes.

It was the rule for Mr. Titcomb to attend to the correspondence and for me to attend to the books. At the time of Mr. Titcomb's death last January the work was left with me. As I was not so situated as to care for all the work falling upon a Librarian it was arranged that all possible correspondence should be attended to by the Secretary and that I should still care for and mail out volumes, except in such cases as they could be sent from the office of the Secretary.

Many of the volumes are nailed in boxes and stored at the Burlington Hatchery which I do not consider a proper place for them. The balance are in our store room in the new State Office Building in Hartford.

The carrying out of the work of Librarian, when taken in connection with the Secretary's work, causes a great amount of duplication of work. Sending the directions for mailing must involve an amount of work equal to the actual mailing of the volumes.

While carrying out the work of Librarian, Mr. Titcomb did a great deal of work to bring the Society before the people who might be interested and in this way sold volumes and brought some help to us, but we are not all so situated as to do this work.

I have not a list of volumes on hand so as to present it at this meeting, but shall plan to make a complete check in the near future. The Society

still lacks copies of the following volumes, and it is hoped members and friends will keep on the lookout for such volumes in order that the permanent library of the Society may contain at least one complete set of its own publications:

VOLUMES THE SOCIETY NEEDS

1877
1878
1879
1880
1881
1882
1883
1887
1902
1903
1905

REPORTS OF STANDING COMMITTEES

REPORT OF MEETING OF THE COUNCIL OF THE SOCIETY

A meeting of the Officers and the Executive Committee of the American Fisheries Society, constituting the Council of the Society, was held at 8:00 P. M. in the Lord Baltimore Hotel, Baltimore, Maryland, on September 20, 1932, those present being:

James A. Rodd, President; H. S. Davis, Vice-President; Seth Gordon, Secretary-Treasurer; Eben W. Cobb, Acting Librarian; Talbott Denmead, Vice-President, Division of Protection and Legislation; and Fred A. Westerman, Chairman, Clarence Birdseye, Thaddeus Surber, and T. H. Langlois, members of the Executive Committee.

Mr. E. Lee LeCompte, Chairman of the Local Committee, was present.

The minutes of the last Council meeting, held at Hot Springs, Arkansas, were reviewed and approved.

After discussion it was voted again to appoint a Program Committee to decide upon the sequence in which papers of the 62nd Annual Program shall be presented. President Rodd thereupon appointed Dr. H. S. Davis, E. Lee LeCompte and Dr. Emmeline Moore to this committee.

The handling of orders for Transactions from individuals and institutions to complete broken sets was discussed, and it was decided that the holders of partial volumes (issued in former years in units of four) shall be re-

quested to return their copies and the Librarian will check and match up complete sets wherever possible, allowing such credit as he may decide for the partial volumes returned. It also was decided that no complete sets shall be broken in order to fill out partial volumes.

Acting Librarian Cobb called attention to the need for untying and rearranging certain volumes, and it was decided that any expense incurred in this connection shall be paid by the Society.

Changes in the list of corresponding members were discussed, and it was agreed that the President, the Secretary and the Librarian shall constitute a committee to decide upon all additions and eliminations.

The President reported that upon the death of Mr. Titcomb he added Dr. Emmeline Moore to the committee to make recommendations for the use of the income from the Permanent Fund. That committee, including Messrs. Surber and Davis, recommended that the income of this fund be expended for abstracting foreign researches dealing with fish culture and related problems, and that the Secretary be authorized to employ a suitable person for this purpose. The committee further recommended that these abstracts be published as an appendix to the Transactions.

After consideration, the Council unanimously approved both recommendations and directed the Secretary to proceed accordingly, and to so use as much of the income from the Permanent Fund as the President and the Secretary may agree upon.

Upon motion made and agreed to, the Secretary was instructed to have the library insured against fire, the Librarian and the Secretary to agree upon the amount.

The Council then considered the question of whether the By-Laws provide ample machinery to fill vacancies. It was the sense of the Council that full power to fill vacancies is now vested in it under the provisions of Article IV of the By-Laws.

The Secretary reported that the permanent securities of the Society are in a deposit box in his name at the Riggs National Bank in Washington, but that the box should be in the name of the Society. He asked for a resolution authorizing it, which was adopted as follows:

Resolved, that the Secretary-Treasurer be authorized to rent a safe deposit box at the Riggs National Bank, Washington, D. C., in the name of the American Fisheries Society, and that access to such safe in the vaults of the Riggs National Bank shall be by the Secretary-Treasurer.

The Secretary-Treasurer reported that $159.25 had been transferred to the Permanent Fund in order to pay for permanent securities purchased for the Society, as set forth in the financial statement, and upon motion this action was approved.

Upon analyzing the status of the Society's general fund it was decided to transfer $1,000.00 additional to the Permanent Fund, and to invest it in the same guaranteed first mortgage 5½% securities as the Society now holds.

Since the membership year now ends on June 30 of each year, the Secre-

tary-Treasurer recommended that the fiscal year of the Society also terminate on that date, and that at future annual meetings a supplemental report be submitted so the Society may have up-to-date information concerning the status of its funds. This change was approved.

The Librarian was authorized to exchange publications as in his judgment shall best advance the purposes of the Society.

Due to confusion in the past, the name of the "Committee on Relations with National and State Governments" was changed to the "Committee on Relations with Federal, Provincial and State Goverments."

The increasing volume of secretarial and accounting work was considered, and upon motion it was decided to recommend to the Society that a total of $350.00 be allowed annually for this purpose.

President Rodd presented a letter from Dr. A. Bajkov, University of Manitoba, Winnipeg, suggesting the desirability of cooperative biological and fisheries investigations of the inland and coastal waters of the Arctic and Subarctic regions of both hemispheres. It was agreed that when economic conditions improve a plan of this kind might well be taken up, and the matter was referred to the incoming President for further action.

There being no further business, the Council adjourned.

SETH GORDON, Secretary.

REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

HENRY O'MALLEY, *Chairman*

In recent years international cooperation in the conservation of our fisheries has progressed rapidly. In no section of the world has so much been accomplished as by Canada and the United States working in close accord. resents the most outstanding piece of conservation work by international good-will by the selection of Mr. Rodd for its President this year, and on at least three former occasions has honored our neighbor by holding the annual convention in Canadian cities. My own relations with Mr. Found, Deputy Minister of Fisheries, and with other dominion and provincial officials, have been most pleasant and have resulted in some highly prized friendships.

In my opinion, the North Pacific Sealing Convention of July 7, 1911, represents the most outstanding piece of conservation work by international agreement. The herd breeding on the Pribilof Islands has been built up in the intervening years from 130,000 to 1,220,000 animals, and now permits an annual take of nearly 50,000 surplus males without detriment to the growth of the herd.

On October 21, 1924, we ratified a convention with Canada for the preservation of the halibut fishery of the eastern North Pacific ocean which faced disaster. Recently the fishing areas had been increased from 500 miles of coastline in 1910 to 2,000 miles in 1930. Despite this increase, the catch has remained nearly the same, the level of production being maintained by in-

creasing the fishing power of the fleet from 200,000 sets of gear units in 1910 to 1,000,000 sets in 1930. On the older southern grounds, seven sets of gear are now required to take as many fish as were caught with one set in 1906. Under the convention of 1924, the International Fisheries Commission, provided for in the treaty, was required to make recommendations to the two governments, for concurrent action as to the regulations necessary to preserve and develop the fishery. Most of you know how difficult it is to secure the passage of a law by your state legislature. You can well imagine how much more difficult it is to get the legislative bodies of two countries to agree. That problem, so far as the Halibut Commission is concerned, was settled by the revised Convention, ratified on May 9, 1931, which provides a simpler and more responsive system of control. The International Fisheries Commission, with the approval of the President of the United States and the Governor General of Canada, may now make regulations essential to the maintenance of this great fishery.

In the Passamaquoddy area, a great power project was held up because of its possible effect on the fisheries of that region. By joint resolution, approved June 9, 1930, Congress authorized an appropriation to defray the expenses of the United States' share of a joint investigation with Canada to determine the probable effect on the fisheries. A corps of experts has been carrying on these investigations for nearly two years, and we expect a report based on these studies to be made shortly.

Most of you are familiar with the fact that certain species of whales are practically extinct and others, chiefly hunted by modern whalers, face the same fate. In September, 1927, the Economic Committee of the Council was instructed by the Assembly of the League of Nations to study the conservation of marine fauna by international agreement. On September 19, 1931, a multilateral convention for the conservation of whales was opened for signature by both member and non-member states. The convention provides for certain control over whaling operations to prevent waste; prohibits the killing of certain rare species; provides for the collection of biological and statistical information, etc. On June 17, 1932, with the advice and consent of the Senate, President Hoover ratified this convention.

For many years efforts have been made to effect means for the rehabilitation of the sockeye salmon run of the Fraser river and Puget sound, which concerns both Canada and the United States, through an international agreement. I am ashamed to admit that interests on this side of the line have succeeded in blocking the ratification of such a treaty. I am still hopeful of seeing an agreement reached on this important matter.

The North American Council on Fishery Investigation, with representatives from Canada, France, Newfoundlnad and the United States, has proven to be one of the most pleasant and helpful organizations to promote fisheries research and avoid duplication of effort. Since its establishment in 1920, it has adhered closely to the policy to correlate the results of investigations in the western Atlantic and make them available to the several countries involved and to bring this about by informal agreement, without overhead charges, and to devote to productive work the funds of the sev-

eral governments available for research purposes. The nineteenth meeting of this Council will be held in Washington, D. C., in October.

This constitutes a very brief review of our foreign relations. In my opinion, it constitutes a chapter of achievements of which we may well be proud. However, the present is no time for resting on our oars. There is much work ahead of us.

Factory ships for handling whales have become well established in the Antarctic. Today California faces the problem of preventing factory ships operating outside the three-mile limit, destroying the highly valuable pilchard, one of the most important fisheries of the continent. Foreign fishing vessels fish off both our coasts. Unless such operations are controlled, these valuable natural resources may face exhaustion. They can only be controlled by international agreement.

My closing suggestion is that this Society lend all possible support in the future, as it has in the past, to have these problems solved by international agreement before it is too late.

REPORT OF THE COMMITTEE ON RELATIONS WITH FEDERAL, PROVINCIAL, AND STATE GOVERNMENTS

LEWIS RADCLIFFE, *Chairman*

Federal and state governments have made rapid strides in increasing their fish propagation facilities in recent years. Instead of eight to ten acres of ponds, the modern hatchery may have from 100 to 600 acres, or more. Investments in large units run from $100,000 to $300,000. The superintendent of such a unit thinks more in terms of the numbers of legal-sized fish he can plant and less of the millions of fry his unit may hatch out.

Through close cooperation with the sportsmen of the country and the education of our people, legislative bodies have been impressed with the importance of conserving our wildlife and the development of the science of water farming. Through stream surveys and studies of watersheds, the foundation is being laid for the development of a proper fish stocking policy. Through scientific studies of fish foods, selective breeding, diseases, and pond management, improved practices are being introduced. All things considered, up to eighteen months ago the future of fish culture in this country had a distinctly rosy tinge.

With the recent widespread demand for curtailment in governmental expenditures, the picture has changed. Not only has almost all expansion of fish-cultural units ceased but appropriations for operations of existing units, for salaries of wardens, etc., have been severely curtailed and in some instances the very existence of the conservation department threatened. And as appears to be a too common American habit, the economy paring is applied most severely to the scientific program upon which we must depend in large degree for progress in the respective fields. All recognize the need for economy in governmental expenditures and our fish culturists and scientists are willing to bear a fair share of the burden. However, curtailment

of expenditures should not go so far as to endanger the wildlife resources of this country and the excellent program for their maintenance which has been developed. A reasonable program for safeguarding and developing them should be maintained.

The existing situation calls for the fullest possible cooperation between the federal, provincial and state governments and private agencies. During the last year the U. S. Bureau of Fisheries has received the hearty cooperation of many agencies. In cooperation with the New York State Conservation Department and the College of Agriculture, Cornell University, there has been initiated a program of fundamental research regarding the digestive enzymes of trout, the extent to which starches and other carbohydrates are utilized, the vitamin requirements of fish, etc. This work is under the direction of Dr. C. M. McCay.

At Rochester, N. Y., the U. S. Bureau of Fisheries has worked out a cooperative arrangement with the State Conservation Department, the Rochester Park Commission and the Monroe County Park Commission, for the use of city and county lakes and ponds for rearing fish, and the establishment of a stocking policy. Rochester University is also cooperating in the scientific phases of the work. Although the project was started late this year, one two and one-half acre pond yielded 22,200 bass for distribution. Such cooperative projects should be developed wherever practicable to utilize available water supplies.

More than fifteen states cooperated with the Bureau in fish cultural work the past season, including joint operation of hatcheries, the collection of eggs, exchange or transfer of eggs, and in other ways. By such means funds for fish propagation work yield far greater results than would be possible by independent action.

In the enforcement of the Federal Law regulating the interstate transportation of black bass, seventy-five fish and game wardens located in thirty states have been appointed by the Secretary of Commerce as deputy black bass law inspectors to assist the federal officers in enforcing the law.

In no field has there been more wholehearted cooperation by the states with the Bureau than in the field of fisheries science. Especially worthy of note has been the cooperation of the Great Lakes states. Material contributions of funds by Michigan, Wisconsin, and the net and twine companies have enabled us to continue these investigations on a worthwhile scale. Furthermore, the spirit of cooperation manifested in providing uniform regulations promises material improvement in fishery conditions. The establishment of advisory committees for boundary waters where uniform regulations are desirable, appears to be the solution of this problem. Such committees should deal only with waters coming within the jurisdiction of each member. For example, it does not appear to be feasible to solve the Great Lakes problems by a single committee but to have committees composed of members with a common interest. Thus there would be a Lake Ontario Committee, a Lake Erie Committee, et cetera.

Because of the need for brevity, your Committee merely outlines the following recommendations for consideration by the Society:

1. It is important that conservation agencies be taken out of politics, and a constructive conservation program be developed under the leadership of properly trained and experienced officials.
2. To this end it is suggested that key positions be filled from a Civil Service register on the basis of training, experience and fitness for the work.
3. Proper regulation of our fisheries to meet emergencies as they arise, and the fact that most state legislatures meet but once in two years, demand greater elasticity in making changes in regulations. To this end, it is recommended that conservation executives be granted greater powers to make changes in regulations as needed.
4. Considering the large expenditures of moneys by federal, state, provincial, and private agencies in fish cultural work, the heavy losses of fish by epidemics, etc., and the need for the services of experts at a moment's notice, it is recommended that steps be taken to secure the establishment of regional offices with a competent personnel to aid individual hatcheries in solving their difficulties and applying the most modern methods in the propagation of fish.
5. The Society should consider the provisions of Senate Bill 263, sponsored by the United States Senate Wildlife Committee, to bring about proper coordination of federal wildlife conservation activities and if it concurs with the Committee in approving of the purposes of the bill, that it urge its passing by the House of Representatives in December. It has already passed the United States Senate.
6. Your Committee urges the Society to approve of the plan for the establishment of advisory committees for boundary waters where uniform regulations are desirable. Each such committee should deal with waters coming within the jurisdiction of each member.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

TALBOTT DENMEAD

In the paper which I read before this Society last year, I tried to cover the Federal Black Bass Law, also the state legislative situation as affecting black bass. Since that time only a few legislatures have been in session and little progress was made in securing new legislation, but some things were accomplished, in which your officers and members had a part, for the better protection of fish.

Most of the work done in the past year, principally educational, was towards obtaining beneficial fish legislation in 1933. I arrived at Hot Springs, Arkansas, the Saturday before our 61st Convention and as usual expressed

a desire to go fishing, and as usual a local deputy fish and game warden came to the rescue. All I had to do was meet him the next morning at 7:00 A. M.

On that memorable Sunday two things occurred worth recording. The first, I caught a black bass that weighed 1¼ pounds when I landed it, but which grew after removal from the water between Sunday and Wednesday to 7 pounds; the second was the "discovery" of the astounding fact that the widely advertised Hot Springs health resort dumped its raw sewage into beautiful Lake Hamilton.

Doubtless you who were present at the banquet last year remember the agitation for eliminating this pollution and the virtual agreement on the part of city representatives and others to construct a modern sewage plant to care for the sewage of the city. I regret to say, in spite of the efforts of those interested, no manner of handling the sewage of Hot Springs has been put in operation, and it still flows on into Lake Hamilton.

In 1933 forty-three state legislatures will be in session, and now is the time this Society should take stock of the situation, acquaint themselves with the legislation required in their states, and lay plans along with the state fish and game authorities and others for preparing, introducing and passing badly needed fish protective legislation.

If the membership will help perhaps next year it can be reported that Maryland passed a law prohibiting the sale of black bass throughout the year instead of four months as the law now provides; that Florida has prohibited the sale of black bass from the St. Johns river; and that at least some of the nine states which now have no statewide close season on black bass have protected these game fish from capture during the spawning season, etc.

One of the outstanding legislative accomplishments during the past year was the passage of an amendment to the Pennsylvania law prohibiting the sale of black bass regardless of where taken. The law had previously allowed the sale of black bass if caught outside the state. This amendment resulted in saving a great number of black bass in southern waters, and probably also many Pennsylvania bass taken illegally within the state and mixed with imported fish and illegally sold. The effects of this one piece of legislation were far reaching and it is hoped some of the fourteen states which still allow the sale of imported black bass will follow the example of Pennsylvania in 1933.

Large quantities of black bass were shipped from Currituck, North Carolina, to Baltimore, Maryland, beginning November 1, 1931. A large part of these fish were intended for reshipment into Pennsylvania as the dealers and shippers had overlooked the change in the law, of which they had been informed. The seizure of several shipments from Baltimore into Pennsylvania by state authorities refreshed the memories of the fish dealers and they were caught one day with about a ton and a half of black bass on their hands. They appealed to the Bureau of Fisheries for information as to the states into which they could legally ship black bass, and a list of

states where they could be legally sold was promptly supplied. In the meantime the wholesale price of black bass fell to 5c per pound.

The market restricted by the change in the Pennsylvania law, the low price, the chance of becoming involved in legal entanglements, and loss of their fish by seizure discouraged shipments and undoubtedly reduced the catch for commercial purposes in North Carolina.

Reports of bass illegally shipped into St. Louis were received and investigated. Several seizures were made for violation of the Federal Black Bass Law, and this illegal traffic was pretty well broken up. Only recently the express agents and state fish and game authorities at St. Louis stated the shipments of black bass into that city had decreased 75% in the last six months, and credited the activities of federal and state officials as responsible for it.

In Maryland waters largemouth black bass were scarce and a very much smaller number than usual reached the markets and were sold during the past year. This, however, was not due to any great extent to law or its enforcement, but principally on account of the influx of salt water into the tributaries of the Chesapeake where black bass are found, resulting in the destruction of black bass, pickerel and yellow perch. Incidentally, in the enforcement of the Federal Black Bass Law, the Bureau has found little or no traffic in smallmouth black bass. If there is a scarcity of this species in any particular section, it will be necessary to look for causes other than sale.

At Wilson lake, the name given to the back waters at Muscle Shoals, Alabama, much destruction of the nests and eggs of black bass, crappie and bluegills had occurred prior to last spring due to the regular raising and lowering of the water level for the purpose of destroying the malarial mosquito. Due to this and other causes, including no close season, the game fish of Lake Wilson were rapidly decreasing. Through conferences and cooperation on the part of the War Department, state health officers and other agencies, changes in water levels were reduced to a minimum last spring during the spawning period without increasing the danger of a malarial outbreak. We have recently been advised that fish conditions so improved that those interested had little fear that the fish would be wiped out by this cause. Incidentally, such changes in water levels are against the law in Colorado.

However, the fish should be protected by a close season during the spawning period, for scientific investigation by representatives of the Bureau has shown a serious lack of oxygen in the main body of the lake, making much of it unfit for fish life. To perpetuate good fishing in this great recreation center, the fish in the shallow waters and tributaries should be given every chance.

After years of preparation and struggle, Mississippi's statewide game and fish law was finally passed and signed by the Governor. This provides for a game and fish commission, the issuance of hunting and fishing licenses, which will provide the necessary revenue for enforcing the game and fish

laws, and may be considered the outstanding legislative accomplishment of the year.

I regret to report that beneficial legislation affecting game fish met defeat in several states during the past year. In Alabama a modern statewide game and fish code was passed by the legislature containing many important features, including protection for the black bass and other game fish. Although sponsored by Alabama's able commissioner, and backed by the sportsmen and conservationists of the state, it met with a pocket veto. Alabama's legislature, in extra session at the present time, does not meet again in regular session until 1935. Information recently received is to the effect that a bill has been prepared, but not yet introduced, abolishing the game and fish wardens and placing the enforcement of the fish and game laws in the hands of the sheriffs.

In South Carolina, whose legislature meets annually, a bill for statewide fish protection was defeated last session, but a bill for further protection of the game fish in Lake Murray, a well-known angler's resort, was successfully passed and became law. A law was also passed prohibiting the export of game fish excepting by a non-resident licensee.

A bill sponsored by a large number of sportsmen was introduced in Tennessee at the last meeting of the legislature but appeared to contain objectionable features as well as beneficial, and met with defeat. It is hoped a bill will be introduced at the coming session and passed, clarifying the present law, which is interpreted to allow fishing for black bass in Reelfoot lake with hook and line during the close season, and that the sale of black bass from all the waters of the state will be prohibited.

In Virginia an attempt was made to take from the Game and Inland Fisheries Commission the power to promulgate regulations for the protection of fish and game. It is believed by many that this bill was introduced in the legislature for the purpose of opening the tributary waters of the Potomac river and other waters to commercial black bass fishing. It is a pleasure to report that this measure was defeated, but not without much effort on the part of those interested. It may be said that defeating injurious legislation, or legislation that repeals good law, is not the least of the accomplishments and duties of the state fish and game authorities and conservationists.

The depression has saved many fish, both game and commercial, for the number of fishing licenses issued last year was greatly reduced in most states, showing a reduced amount of angling, and pollution materially decreased in many places owing to the shutting down of a large number of industrial plants. For the first time in many years sea horses and striped bass have been found in numbers close to the heart of New York City, due it is believed to improvement in water conditions, mainly the result of inoperative industrial plants which during better times discharged injurious substances into the water surrounding the city.

These things have proven helpful to our fishes, sorely pressed by drought and scarcity of suitable water. It would be wise for this Society at this time to actively interest itself in suppressing pollution. If the proper authorities could be approached in many cases a way might be found to re-

quire at least some of the industrial plants, now idle, to make provision for disposal of their waste, perhaps as a by-product, or by demonstrating to them some modern method of disposal previous to their resuming operations.

The fish culturist and scientist, as well as the angler and commercial fishermen, are interested in increasing the numbers of fish, but their energies and knowledge are wasted in raising, caring for and liberating fish in polluted waters. Every state in the Union has a law prohibiting, restricting or regulating pollution of waters. Some do not fully cover the subject. A study of the pollution laws of the states, with a view to improving them, is planned for the near future. It is a good thing to have adequate laws governing pollution, although much can be accomplished by cooperation rather than by coercion.

There was some congressional activity during the past year on matters pertaining to conservation, and attention is called to the following:

A bill (S. 2370), regulating interstate transportation of lobsters, was introduced in this session of Congress for the purpose of granting these valuable animals further protection. It was especially aimed at the importation into this country of small lobsters which competed unfairly with our native lobsters. This measure, while heartily endorsed by some of the states, met with opposition from others and is pending. If passed the law will be administered by the Bureau of Fisheries along with the Federal Black Bass Law.

A bill (H. R. 163) to extend the federal law prohibiting oil pollution of coastal waters to include inland waters, on the ground that such pollution is a menace to navigation, is in the same boat, but its friends hope to obtain at least a favorable report, if not its passage, at the coming session of Congress.

The bill known as the Coordination Bill (S. 263), designed to bring about closer cooperation between government agencies where the welfare of our wildlife is involved, and which would materially assist in the advancement of fish culture, scientific investigations, and result in economies, was the first bill that the Senate passed almost unanimously. It was reported by the House Committee to which it was referred but did not come to vote in the House of Representatives. It is believed the chances for its passage at the coming December session are good.

The bill (S. 2162) to establish an experimental station for investigating problems in connection with the conservation of fish and game for some reason has not been reported out by the Senate Wildlife Committee. As it will require an appropriation to put this measure in effect, perhaps it will be necessary to wait awhile before progress can be made with this measure.

It has been suggested that the Federal Black Bass Law be amended to include game fish other than black bass, but with the small force at the disposal of the Bureau under the present reduced appropriations it seems best to take no steps to accomplish this for the present.

It may be news to some of you that the City of Washington, the Capital of the Nation, has no modern sewage system and discharges the bulk of its raw sewage into the Potomac river. It would not seem that such a condi-

tion should require investigation to ascertain whether it is harmful. Nevertheless, Senate Resolution 44 was passed requesting the U. S. Public Health Service to investigate conditions resulting from this crude disposal of the city's waste, with a view to determining the extent to which such disposal constitutes a menace to public health, is an annoyance to residents, and destroys fish and oysters. The request is being complied with and the report to Congress is awaited with interest.

You are probably all familiar with the situation in Currituck sound, North Carolina, where the removal of the locks from the Chesapeake and Albemarle Canal caused an influx of salt water and sewage into Currituck sound and destroyed the natural fresh water grasses, polluted the shallow waters, and ruined an ideal habitat of the black bass and the wild duck. The year 1932 saw this situation remedied by the restoration of a lock at a cost of around one-half a million dollars appropriated by Congress. This should restore this well-known wildlife area to its former condition.

It will be a pity if the State of North Carolina does not seize the opportunity afforded by the present situation to prohibit the sale of black bass taken from the waters of Currituck. Certainly these game fish are worth more to the citizens of that great state than 5c to 12c per pound in the Baltimore markets, at which prices the North Carolina fishermen derive little or no profit after deducting expenses. If properly cared for and exploited the waters of Currituck and vicinity would be a veritable angler's paradise, and a gold mine for the citizens of the state who would be called upon to provide the visiting sportsmen with boats, bait, groceries, gasoline, fishing tackle, board at hotels and private houses, guides, etc.

This can be accomplished by regulation promulgated by the North Carolina Fisheries Commission, now merged with the Board of Conservation and development, without recourse to the state legislature, although it might be best for the state to enact a law prohibiting the sale of largemouth black bass regardless of where taken. The state law now prohibits the sale of smallmouths.

I do not want to take your time to outline the needs of the various states to perfect their laws and provide adequate protection for the black bass. This is set forth in full in a table prepared in the Bureau of Fisheries and published in the Congressional Record of July 5, 1932, copies of which may be obtained on application to the Bureau of Fisheries. It is hoped all present will inform themselves of the important changes needed in the laws of their respective states and take part in preparing, introducing and passing bills to cover the defects.

All state fish and game authorities have suffered the last year or two by reduced funds. The appropriation for the enforcement of the Federal Black Bass Law this year was cut 25%. It is understood the business of issuing licenses has picked up in many states this fall. More and better enforcement of both federal and state fish and game laws is needed but cannot be had without funds. As it is good policy to protect what we have, let us hope some way will be found in the near future to obtain necessary funds for proper enforcement of both state and federal laws for protecting and increasing our valuable game and food fish.

REPORT OF THE DIVISION OF COMMERCIAL FISHING

N. B. Scofield

Anyone who has been in touch with the fisheries of the United States and Canada could not fail to observe the rapid advance, during the past few years, in the application of scientific methods and research to fisheries problems.

Fisheries laboratories have been established by the United States and Canadian governments and by some of the individual states, and competent research staffs have been built up.

The basic principles of fish culture which have been trustingly accepted in the past are under scrutiny and are being subjected to experimental methods for determining the truth.

Notable advances have been made in aquiculture, as a result of the employment of research. One of the most important results along this line is the impetus which has been given to oyster culture both on the Atlantic and Pacific coasts.

Research has been extensively applied in the field of fisheries technology, by federal and state governments, and especially by commercial companies themselves.

The most important, though less conspicuous, advances have been made in the application of scientific methods and research to the problems involved in conserving the supplies of fish on which the commercial fisheries depend for their raw material.

Our U. S. Bureau of Fisheries leads in this work, but only a few of the states have put their fisheries conservation work on a sound scientific basis.

We are no longer in any doubt as to what is the most necessary and fundamental thing to do in conserving our fisheries resources. That most necessary and fundamental thing is a system of gathering adequate and continuous statistics of the commercial fish catch.

The first thing the investigator needs to know is whether the supply of fish can stand the strain of the fishery. This can be determined only from adequate statistics of the commercial catch extending over a period of years.

In this country the states have jurisdiction over their fisheries and they alone are responsible for their protection. So it is up to the states to establish proper statistical systems. A few of the states have done this, but too many of the states with important fisheries have done nothing.

Five years ago there was presented to this society a report of the Division of Commercial Fishing entitled "Statistics—The Basis for Legislative Action," by the Vice-President, Lewis Radcliffe, in which he forcefully set forth the necessity for states to establish adequate fisheries statistical systems. He presented a "Proposed Bill for the Collection, Compilation and Dissemination of Fishery Statistics," which was drafted by the statistical section of the Scientific Division Committee of the U. S. Fisheries Association. He urged the adoption of this bill by the states. The Society, by resolution, urged each state to provide adequate legislation for the collection of fishery statistics.

The response to these pleas was not what it should have been. I earnestly request all members to re-read the short but important report of Mr. Radcliffe in the Transactions of the Society for 1927.

With the hope of reviving interest in fishery statistics, a paper entitled "Comments on Fisheries Statistics Collected in California," by W. L. Scofield, of the California State Fisheries Laboratory, has been prepared for the present program of the Society.

APPOINTMENT OF CONFERENCE COMMITTEES

Auditing: Guy Amsler, Chairman, James N. Gowanloch, John Van Oosten.

Resolutions: M. C. James, Chairman, Fred A. Westerman, N. J. Atkinson, Burnie Maurek, William C. Adams, T. H. Langlois, T. Surber.

Time and Place: E. Lee LeCompte, Chairman; J. B. Dauenhauer, Jr., William H. Reinhart, Harry Neelley, Ward Bower, Arthur L. Clark, M. S. McMurtrey.

Nominations: Eben W. Cobb, Chairman, C. F. Culler, A. B. Cook, Jr., Will Tucker, George C. Embody, Charles O. Hayford, N. R. Buller.

REPORT OF CONFERENCE COMMITTEES

AUDITING COMMITTEE

DR. GOWANLOCH: The Auditing Committee submits the following report:

The Auditing Committee has checked the books and vouchers of the Treasurer and finds the report of the Treasurer as submitted to be correct.

We recommend that the total appropriation for clerical services for the year 1932-33 be $350.

The Secretary-Treasurer informs the Auditing Committee that when he attempted to have some member of the Society check with him the securities of the Permanent Fund, which are held at the Riggs Bank in Washington, he was unable to find a member available. Your committee recommends that in the future one of two courses be adopted: either that the President appoint a member of the Society for this formal check of securities of the Permanent Fund, or that a certified record of the bank where these securities are held be presented as one of the documents for audit.

Your committee feels that it must comment upon the exact and excellent manner in which the financial records of this Society are kept.

Adoption of the report was moved and carried unanimously.

COMMITTEE ON RESOLUTIONS

MR. JAMES: The Resolutions Committee received a considerable number of resolutions. Our report is quite long, but I believe all the resolutions merit the consideration of the Association. They are as follows:

John W. Titcomb

BE IT RESOLVED, That this Society feels great sorrow because of the passing away of one of our most interested and well known workers, John W.

Titcomb, who was born February 24th, 1860, and died in Hartford, Conn., after a short illness, on January 26th, 1932.

He organized the Vermont Fish and Game League in 1890, and later held positions as Chairman of the Vermont Fish and Game Commission; Superintendent of a federal hatchery; Chief, Division of Fish Culture, U. S. Bureau of Fisheries; State Fish Culturist, State of New York; and Superintendent of the Connecticut State Board of Fisheries and Game, which position he held at the time of his death. He became a member of this Society in 1892, and always worked faithfully not only for the good of the Society but for all which it represented.

FURTHER RESOLVED, That a copy of this resolution be sent to his son and to his daughter whom he has left behind him.

Curtailment of Appropriations

RESOLVED, That the American Fisheries Society views with grave concern the tendency of some of the state legislative bodies and Congress to apply cuts in appropriations more severe on the scientific and conservation work than on other branches; and in view of the fact that many years are required to bring back the natural resources, once impaired, urges a more equitable distribution of cuts in appropriations.

Impairment of Activities of the Bureau of Fisheries

RESOLVED, That the American Fisheries Society looks with disfavor upon the recent attempt in Congress to transfer functions of hatchery units to the states, and urges that the present organization of the United States Bureau of Fisheries be retained unimpaired. The combined efforts now being made by national and state governments are essential to the maintenance of game fish and game birds.

Fisheries of the Great Lakes

WHEREAS, Scientific investigations by the U. S. Bureau of Fisheries have shown that the trapnets now in general use on Lake Erie retain and destroy large quantities of small fish, and

WHEREAS, These investigations have shown further that this destruction and waste may be eliminated to a large extent by enlarging the mesh in certain parts of the lifting crib of the commercial trapnets and thereby in various ways benefiting the fishing industry, and

WHEREAS, The laws of the State of New York already provide for a large mesh in trapnets on Lakes Erie and Ontario; therefore,

BE IT RESOLVED, That the American Fisheries Society strongly urge the adoption of the trapnet recommended and developed by the Bureau of Fisheries to replace those with small mesh and the enactment of adequate legislation to assure such adoption of this trapnet.

BE IT FURTHER RESOLVED, That a copy of this resolution be sent to the governors of the several states bordering on the Great Lakes, to the Deputy Minister of Game and Fisheries of the Province of Ontario, and to the Deputy Minister, Dominion Department of Fisheries, Ottawa, Canada.

Deep Water Trapnets

WHEREAS, The deep water trapnet is found to be a very efficient net in the taking of whitefish and other fish in comparison to pound nets, gill nets and seines, commonly used on the Great Lakes, and

WHEREAS, The use of deep water trapnets is rapidly spreading throughout the upper Great Lakes through competition among fishermen in spite of widespread objection to their use, and

WHEREAS, The use of these nets is detrimental to the fisheries resources of the Great Lakes as evidenced by the depletion and destruction of the whitefish fisheries on the grounds where they have been extensively used, principally Lake Ontario and upper Lakes Huron and Michigan, therefore,

BE IT RESOLVED, That the American Fisheries Society strongly urges that adequate legislation be adopted at the earliest possible time to regulate and control the use of deep water trapnets and pound nets to conserve the valuable whitefish fisheries in waters of the Great Lakes, especially in Lake Huron, Lake Michigan and Lake Superior.

BE IT FURTHER RESOLVED, That a copy of this resolution be sent to the Deputy Minister, Dominion Department of Fisheries, Ottawa, Canada; the Deputy Minister of Game and Fisheries of the Province of Ontario, Canada; and to the governors of the several states bordering on the Great Lakes.

Uniform Seasons on Lake Erie

WHEREAS, The cisco of Lake Erie is threatened with complete commercial extinction, and

WHEREAS, One important step has been taken in its preservation by the abolition of the bullnet effective in 1933, and

WHEREAS, It is deemed urgent to provide further protection for this species as well as for other species in the lake, and

WHEREAS, The opening of the fishing season on Lake Erie before March 15 has repeatedly been shown to be destructive to spawning fish and to fishing gear alike; therefore,

BE IT RESOLVED, That the American Fisheries Society urge the states and the province bordering on this lake to adopt a uniform closed season on Lake Erie from December 1 to March 14, inclusive, except that New York be permitted to continue fishing for whitefish until December 21 in each year in accordance with the agreement made between this state and the other commonwealths on Lake Erie at the conference held at Buffalo, New York, on October 12, 1931.

BE IT FURTHER RESOLVED, That a copy of this resolution be sent to the governors of the several states bordering on Lake Erie, to the Deputy Minister of Game and Fisheries of the Province of Ontario, and to the Deputy Minister, Dominion Department of Fisheries, Ottawa, Canada.

Complete Protection of Sturgeon

WHEREAS, The sturgeon of the Great Lakes is and has been threatened with complete extermination, and

WHEREAS, This species is given complete protection in the United States waters of Lakes Superior, Michigan (Illinois excepted) and Huron, and

WHEREAS, The sturgeon was until recently given complete protection by the law in Ohio but because of the lack of complete protection in the other states on this lake and in the province of Ontario this restriction was removed until such protection is given in these other states and the province; therefore,

BE IT RESOLVED, That the American Fisheries Society earnestly urge the states and the province to take the proper steps necessary to give complete protection to the disappearing sturgeon of the Great Lakes and thus save if possible this important species from complete extinction.

BE IT FURTHER RESOLVED, That a copy of this resolution be sent to the governors of the several states bordering on the Great Lakes, to the Deputy Minister of Game and Fisheries of the Province of Ontario, and to the Deputy Minister, Dominion Department of Fisheries, Ottawa, Canada.

Coordination of Federal Conservation Activities

WHEREAS, There has been passed by the United States Senate a bill known as Senate Bill No. 263, providing for the coordination of all federal conservation activities, and

WHEREAS, This measure constitutes a forward step in the administration of fisheries and wild life resources without involving increased expenditures or modifying existing organizations,

BE IT RESOLVED, That the American Fisheries Society urges favorable action by the United States House of Representatives on the above Senate Bill No. 263, at the earliest possible date.

Submission of Papers for Presentation at Annual Meetings

WHEREAS, Many papers are submitted at a late date for presentation at the annual meetings of this Society, thus making it impossible to prepare in advance a logical sequence in the program of the meetings,

BE IT RESOLVED, That all papers not submitted to the Secretary one week in advance of the opening day of the annual meeting shall not be included in the printed program, and shall be presented at the meetings only at the discretion of the Program Committee, and included in the Transactions of the Society only at the discretion of the Publications Committee.

Committee on Scientific Names of Fish

WHEREAS, A wide diversity exists on this continent in the use of common names of fishes, and

WHEREAS, Such diversity of usage leads to much confusion in fish-culture problems and legislation,

BE IT RESOLVED, That a permanent Committee be appointed by the Executive Council of this Society to prepare and submit for publication a list of standard, common names corresponding to the accepted scientific names, and that the said Committee have power to add to this list from time to time, as proves necessary.

AND BE IT FURTHER RESOLVED, That the members of the American Fisheries Society adopt the use of these names in general practice and urge their universal employment in all legislation.

Pollution of the Potomac River

WHEREAS, The tentative report of the United States Public Health Service with reference to the pollution of the Potomac watersheds emphasizes the previously well known facts concerning the misuse of these waters at the nation's capital,

BE IT RESOLVED, That the American Fisheries Society deplores this lamentable condition and further urges that every agency concerned with its elimination take every possible step to eliminate this pollution and provide clean water at the nation's capital in the interests of conservation and public health.

Protection of Black Bass

WHEREAS, The meetings of a large number of state legislatures during the coming winter affords opportunity for eliminating deficiencies in laws affecting black bass, particularly with reference to protection during the spawning season and the commercialization of the species; therefore,

BE IT RESOLVED, That the American Fisheries Society reiterates its previously expressed attitude to the effect that every possible protection must be provided in state laws for this pre-eminent game fish.

The Biologic Forces of Nature

WHEREAS, The previous generation accepted the dogma that competition is the progressive element in human affairs; and

WHEREAS, This dogma was based upon incomplete biologic knowledge, and the belief that competition signified the biologic struggle for existence; and

WHEREAS, Undue emphasis has been placed upon the minor functions of water, such as use in manufactures, power, and navigation, as compared to the original biologic functions of water, the basis of all useful business, progress and prosperity; and

WHEREAS, The prosperity of the farm laborer and of the capitalist has become impaired by the unnecessary wastage of the public waters by unwise drainage and diversion of public waters for essentially minor purposes;

BE IT RESOLVED, That the American Fisheries Society emphasize its belief that undue emphasis has been placed upon competition as a part of cooperation; and

BE IT FURTHER RESOLVED, That all business, state and federal officials, and organizations be urged to cooperate upon principles and practices based upon broad scientific knowledge, and that this cooperation shall include such broad criteria as shall adequately provide facts for the conservation of those biologic elements and forces of nature which govern all life, prosperity and economic justice.

Acknowledgment of Courtesies

RESOLVED, That we express our sincere appreciation for the attractive program and cordial hospitality which have characterized the Sixty-Second Annual Meeting of the American Fisheries Society, and that we extend our sincere thanks to His Excellency, Governor Albert C. Ritchie of Maryland, to His

Honor, Mayor Howard W. Jackson, of Baltimore, and to the various Game and Fish Associations which have participated, as well as to the Maryland Conservation Department, whose officials are largely responsible for the success of the meeting.

We also express our appreciation to the Baltimore Association of Commerce for courtesies received and to the press.

We further express our appreciation to the Management of the Lord Baltimore Hotel for the many courtesies extended which have contributed greatly to the comfort and pleasure of our members and to the success of our meeting.

COMMITTEE ON TIME AND PLACE

MR. LECOMPTE: I have the honor to report the findings of the Time and Place Committee jointly with the Time and Place Committee of the International Association, as follows:

Your Committee met aboard Steamer *F. C. Latrobe* en route from Annapolis to Baltimore in connection with the Time and Place Committee of the International Association of Game, Fish and Conservation Commissioners, of which Mr. James Brown is Chairman, and after a thorough discussion and submission of invitations received it was unanimously voted that the International Associaton of Game, Fish and Conservation Commissioners and the American Fisheries Society hold their joint conferences at Indianapolis, Indiana, the third Monday of September, 1933.

The report was unanimously adopted.

COMMITTEE ON NOMINATIONS

MR. COBB: The Committee unanimously recommends the following:

Officers

President—H. S. Davis
Vice-President—Fred A. Westerman
Secretary-Treasurer—Seth Gordon
Librarian—Eben W. Cobb

Vice-Presidents of Divisions

Fish Culture—C. R. Buller
Aquatic Biology and Physics—Edward L. Wickliff
Commercial Fishing—John Van Oosten
Protection and Legislation—Guy Amsler
Angling—Samuel B. Locke

Executive Committee

Clarence Birdseye, *Chairman*

A. G. Huntsman	Fred Foster
Walter Shirts	I. T. Quinn
Lewis Radcliffe	Dennis Winn

Committee on Foreign Relations

James A. Rodd, *Chairman*

John L. Farley	William C. Adams
Frederic C. Walcott	Frank M. Warren

Committee on Relations with Federal, Provincial, and State Governments

Henry O'Malley, *Chairman*	A. B. Cook, Jr.
W. F. Thompson	W. A. Clemens
William J. R. Harkness	Talbott Denmead

A Committee on Publications has been elected at periods in the past, but our Constitution calls for its appointment by the President of the Society, so we did not include that, thinking it would be better for the incoming President to make his own appointments.

On motion regularly moved and seconded, the report of the Committee was unanimously adopted.

RETIRING PRESIDENT RODD: I will ask Dr. Van Oosten and Mr. Cobb to escort the newly elected President, Dr. Davis, to the chair.

Dr. Davis was escorted to the chair, amid applause.

RETIRING PRESIDEND RODD: I introduce to you Dr. Davis, your new President. In doing so I congratulate Dr. Davis upon the honor which has been conferred upon him, and I also congratulate the Society upon the wisdom of its selection.

PRESIDENT-ELECT DAVIS: Thank you, Mr. Rodd. I want to congratulate Mr. Rodd on a most successful meeting, a result achieved largely through his untiring efforts. As a member of the Society I feel that our meetings are growing better and better each year. To my fellow members I wish to express my deep appreciation for the signal honor they have conferred upon me, and to assure them that to the best of my ability I shall endeavor to follow worthily in the footsteps of a long line of distinguished predecessors, who have played no small part in making this Society what it is today. I sincerely hope I shall see you all at Indianapolis next year, along with many others, and I ask your cooperation in making that meeting one of the best the Society has ever held. I thank you from the bottom of my heart. (Applause.)

MR. LECOMPTE: I move that the Society adjourn, to meet the third week in September, 1933.

DR. VAN OOSTEN: I second the motion.

Accordingly the meeting adjourned at 4 P. M.

In Memoriam

W. E. Albert

C. N. Candee

H. F. Hurlbut

Charles M. Struven

John W. Titcomb

R. P. Whiteside

PART II
PAPERS AND DISCUSSIONS

THE FISHERIES OF CHESAPEAKE BAY

SWEPSON EARLE
Conservation Commissioner of Maryland

Any discussion of the fisheries of Chesapeake bay would be incomplete without a description of this great body of water itself and a brief glimpse into its early history.

The white man's knowledge of Chesapeake bay began in April, 1607, when Captain Christopher Newport's little fleet of three vessels was involuntarily blown into the mouth of the Bay. Scudding before a furious gale, these storm-tossed barks found a haven of rest and a safe anchorage in the waters of Hampton Roads. Thereupon followed the settlement of Jamestown on the James river, which marked the beginning of the Virginia Colony.

Almost three decades thereafter, the ARK and the DOVE, under the leadership of Sir Leonard Calvert, sailed up the Bay and into the broad waters of the Potomac river, where they dropped anchor off St. Clement's (now Blakistone) Island, in March, 1634. Nearby on the St. Mary's river was established the first city of Maryland, St. Mary's City, which remained the capital until 1692, when it was removed to Annapolis.

The Chesapeake bay may truly be classed as one of the greatest inland seas in the world. Lying wholly within the boundaries of Virginia and Maryland, it comprises an area of 5,000 square miles, has a shoreline of 4,612 miles, and from Cape Charles at the mouth to the head of the Bay is 195 statute miles. The courses up the Bay for 161 miles do not vary more than two points of the compass. The width varies from three to twenty-two miles. Its greatest depth is 156 feet of water. Flowing into this "Mother of Waters," as the Indians called the Chesapeake, are 150 tributaries and branches, most of which are open to commercial navigation, and which range in length from a few miles to 100 miles. The combined length of the navigable water is over 1,750 miles. Captain John Smith, that intrepid Englishman, explored the waters of the Bay as far as its head, and in the year 1608 made a map of the region which is still a source of admiration to cartographers.

Our trip down the Patapsco and out in the Chesapeake today to visit the capital of Maryland coincides very well with a discussion of the fisheries, because even this brief glimpse will serve to show you how admirably the State is supplied with salt water, and how accessible Baltimore is to the sea.

I feel we have reached a very important period in the history of our seafood industry. For many years Maryland had no worries about her seafood supply. The demand was negligible and the sup-

ply abundant. This state of affairs existed up until the Civil War, when improved transportation facilities broadened the market for the Bay products. During this period and up until the early part of the present century, the water crops, particularly the oyster, were in great demand, with the inevitable result of overfishing, waste, and consequent depletion.

In Maryland's palmiest days of oyster production, between 1880 and 1890, as high as 15,000,000 bushels of oysters a year were harvested. Those days of plenty may be termed "the romantic era" of the Chesapeake. Colorful indeed was this period, when a fleet of 800 or more dredge boats, manned by fearless skippers and crews shanghaied from the dance halls and saloons of Baltimore's waterfront, ruled the Bay and defied the authorities. Many tales of hardship and brutality were told about those shanghaied crews, who were obliged to wind in the heavy dredges from dawn to sunset, exposed to wintry winds and sleet, and often at night to take part in the raids on tongers' grounds in the forbidden waters of the tributaries. Many battles were fought during this period between the lawless dredgers and the oyster police, and one of the most famous occurred in 1888 in Chester river, which is on the Eastern Shore just opposite the Patapsco, when the police steamer was engaged by 49 dredge boats armed with rifles, ammunition and "hard liquor." In that battle, two dredge boats, called "pungeys," were sunk, and eleven men lost their lives.

Highly engaging are the tales of those days on the Chesapeake, but the destruction wrought by these outlaws, who in their greed and wastefulness cleaned up whole beds of oysters and their shell foundations, can never be wholly repaired. An awakened public interest in the conservation of this diminishing water resource finally brought about the enactment of remedial legislation, and the machinery for protecting and upbuilding this great industry was set in motion. In the year 1916, the first real step in the reorganization of the state's agencies in charge of the natural resources took place. In that year the Conservation Commission was created, placing under one head the Shell Fish Commission, Fish Commissioners, State Game Warden and State Fishery Force (oyster police boats).

One of the first acts of the newly formed Conservation Commission was the replacement of the picturesque, but antiquated, sailing craft of the old State Fishery Force with modern, efficient power boats. Through successive administrations, additions and improvements have been made to the patrol fleet, until today, with one steamer, nineteen power boats and seven auxiliaries, it is one of the best equipped water forces on the Atlantic Coast.

In addition to efficiently carrying out the state laws on oysters, crabs, fish, etc., progress has been made in rebuilding certain of the depleted industries. For instance, the state is planting approximately 1,000,000 bushels of oyster shells a year on such natural bars

in the Bay and tributaries as are in need of cultch for oyster spat. Results are already discernible from this work, which has been going on for three years; the oyster production last year having shown an increase of nearly 300,000 bushels over the previous year, and indications are that this year will show an additional increase of a quarter of a million bushels.

During the latter part of 1931, the Chesapeake Biological Laboratory, located on Solomons Island overlooking the Bay and the Patuxent river, was begun, and was completed in May of this year. Formal class work in biological subjects was started this year, and independent investigation of the marine life of the Bay is to be fostered. A number of leading colleges and universities of Maryland took part in the first season's work. Operated in conjunction with the Laboratory is a 1,000 acre oyster farm set aside by the state for experimental purposes.

The New England oyster growers refer to the Chesapeake product as a "wild oyster." We prefer to call it a "naturally grown oyster," the New England designation being connected in our minds with oysters which are allowed to develop regardless of size or form. While our product is not carefully cultivated like the oyster beds of the north, which are under private ownership, nevertheless, our oysters are cultivated on the natural bars by the watermen themselves, under strict police supervision and a strict cull law. Oysters must be three inches in length from hinge to mouth and must not run more than 5% undersized to the cargo.

The terms "oyster bars" and "oyster rocks," while so familiar to the people of the Bay Country, are sometimes confusing to others, as in the case of a certain gentleman from one of our inland states who interpreted an oyster bar as "a place where you eat oysters and drink beer." On another occasion, a health commissioner, who came from Chicago several years ago to investigate the sanitary condition of Maryland's oyster producing waters, admitted that he thought oyster rocks projected above the surface of the water, and that seagulls assembled on them and might possibly be a source of pollution.

And in speaking of pollution, that very serious menace to aquatic life, Maryland waters are reasonably free of it. The State Department of Health cooperates with our department in making a sanitary survey annually, and any area in close proximity to a tidewater town is zoned off from public oystering. The City of Baltimore, when installing its modern sewerage disposal system, expended $2,000,000 for a suitable plant.

Two states situated as are Virginia and Maryland, in joint control of a valuable water area, often find themselves confronted with difficult problems in fishery conservation. It is not possible to build a wall along the boundary line between the two states and prevent the fisheries of one state from entering or leaving the other, although some of our legislators have evidently thought so. The best illus-

tration we have ever had of the impracticability of legislating for a common fishery according to the wishes of the individual states rather than for the good of the fishery as a whole is the blue crab of Chesapeake bay.

This member of the crustacean family was not greatly in demand until about 1900, with the advent of refrigeration in transport service, and then, as is usual, overfishing and waste occurred, and the production declined. Various conservation measures were advanced to save the crab, but no real study had been made of this fishery until 1917, when the United States Bureau of Fisheries, with its customary willingness to cooperate with the states, detailed one of its scientists to investigate the life history of the crab.

Dr. E. H. Churchill undertook the work, and the report of his findings developed much new and valuable information about the crab. For instance, it was found that 80% of all female crabs pregnant with eggs were found in winter in the waters of the lower Chesapeake near the Virginia Capes, and 80% of all the males remained in Maryland. Following the hatching out of the young crabs in Virginia in the spring and early summer, shedding commences. In its earliest stage, the zoea as it is called, and even after approximately five sheddings, when it has reached the so-called megalops stage, it in no way resembles the mature crab. After reaching this latter stage, however, it begins its northward migration to the grassy bottoms of Tangier sound, where the sun warms the water and facilitates the shedding process. It takes about two years, or some fifteen sheddings, the crab being alternately a soft and then a hard crab, to attain maturity. The northward migration continues, and we find crabs as far north as the Elk river in the head of Chesapeake bay and as far up the Potomac as Alexandria. When the female reaches maturity, mating occurs, and she starts her southern migration to Virginia waters, where the saltier waters of that region develop the eggs, and the cycle is again completed. Thus it may be seen that the entire Bay region is required for the proper development of the crab.

The government, after its investigation, recommended that the female crab bearing the egg-sponge should be protected at all times, and the so-called "green" crab, heretofore placed in floats to shed, be allowed freedom until reaching the peeler stage. Although Maryland passed the necessary laws, Virginia, which controlled the destiny of the crab, was slow to heed this advice. The production continued to decline until in 1925 it had reached the low ebb of 29,000,000 pounds. After a number of meetings and conferences between the commissioners and committees of the two states, Virginia in 1926 passed legislation protecting the female crab pregnant with eggs, and the two states have worked hand in hand on this question ever since. As a result, last year the crab production, according to government statistics, had jumped to 68,000,000 pounds.

With the increase in the production of crabs in Chesapeake bay, efforts are now being made to create new markets to utilize the surplus, and at the same time to combat the invasion of Japanese and Russian crabmeat, which, after its success on the west coast and some of the mid-west sections, is now making extensive preparations to capture the eastern market.

In addition to its oyster and crab industries, the Chesapeake is well supplied with a variety of salt water fish, many of which are native forms. Shad, mackerel and herring during the spring migration season, striped bass, blue fish or tailor, sea trout and largemouth bass are among the finer varieties of fish that frequent the Bay and its tributaries. The latter fish are considered game rather than commercial varieties, although they too find their way to the markets of the region. Their value as game fish, however, outweighs their commercial value, because of the large numbers of sportsmen which they draw to the Bay.

Several weeks ago, I instructed the deputy commanders of the State Patrol Fleet to record the number of boats and persons engaged in sport fishing within their respective districts during a period of one week beginning August 22nd. The results were astounding, even to the fishermen themselves. The figures showed that 16,805 persons fished on the Chesapeake or its tributaries during that week, using 2,621 boats rented to them by the commercial fishermen and watermen in the several fishing communities. It was roughly estimated that $100,000 was left behind by these sportsmen during one week in August.

In recent years trolling for striped bass and blue fish has lured many anglers from the fresh water streams of the state to enjoy this very different type of fishing on the broad waters of the Chesapeake. This summer blue fish have been so plentiful that it is not uncommon for a boat in a couple of hours to take one or two hundred fish. Striped bass in previous years have been more plentiful than blue fish, but overfishing and the use of destructive nets have reduced the numbers in our waters. Near the head of the Bay, where the Susquehanna river enters into it, striped bass weighing fifteen pounds, the maximum size, are taken.

Through the zealous efforts of the sportsmen's organizations of the state, the purse net has been outlawed in Maryland waters. This net, together with the sunken anchored gill net, which takes striped bass during their period of hibernation, are considered the most destructive types of fishing gear used in Maryland waters.

The commercial fishermen of Maryland, like those of Virginia, utilize every good point leading from the shore line for their pound nets, in which are taken the delicious shad, as well as trout, striped bass and other varieties. The Commissioner of Fisheries of Virginia, Honorable Richard Armstrong, is cooperating with us in endeavoring to curtail the length and number of nets in the lower bay, so

that fish entering the Capes may reach the spawning grounds in the upper Bay in greater numbers. The State of Maryland is doing its best to clear nets from the rivers where our commercial fish hatcheries are located. These hatcheries turn out from 12,000,000 to 15,000,000 shad fry annually and several hundred million white and yellow perch.

Maryland is now endeavoring to follow the lead of other states in the Union in giving proper protection to the black bass by preventing its sale within the borders of our state.

By an order of the Public Service Commission of Maryland, under date of January 13, 1926, granting the Susquehanna Power Company permission to establish a dam on the Susquehanna river at Conowingo for the purpose of generating electricity, special provision was made for the placing of suitable fishways to meet the approval of the Conservation Department. When the time came to consider plans for fishways, the department, realizing that they would be ornamental rather than practical, since no device had ever been designed which could lift shad and other soft fish a hundred feet to clear the dam, turned down such plans as were offered. After negotiations covering a period of time, the power company, in lieu of fishways, which would be impracticable, arranged to pay the States of Maryland and Pennsylvania $4,000 each, annually, the money so provided to be used in stocking the pool above the dam with fish.

This arrangement was agreed to, and since 1928, the two states have placed in this pool, now called Conowingo lake, 75,000,000 fish, including large and smallmouth bass fry and fingerlings, lake herring, crappie, pike, yellow perch, pike-perch, sunfish and minnows.

Instead of erecting a fishway, which would have cost $100,000 or more and then not fulfilled its purpose, the anglers of Maryland and Pennsylvania are now enjoying the benefits of the stocking of this large area of water with fish, and in the next few years it is anticipated that Conowingo lake will prove one of the best fishing grounds in the state.

Discussion

PRESIDENT RODD: I understand that Mr. Richard Armstrong, Commissioner of Fisheries of Virginia, is on board. It gives me much pleasure to call on Mr. Armstrong.

MR. RICHARD ARMSTRONG (Virginia): You all know that you are passing over Chesapeake bay, but you perhaps do not know that it is the greatest body of temperate zone water in the world for the production of sea foods. The figures that could be cited to you would probably mean nothing, unless I told you at one time it produced 18,000,000 bushels of oysters.

You have here a body of water that is some 180 miles long, fed by some of the largest rivers on the Atlantic coast, the Susquehanna, Potomac, Rappahannock, York and James, and many smaller rivers. It is a shallow area, ranging from about a foot to thirty or forty feet, and for the most

part it is a great, shallow inland lake. It is nice to have at our front door, as it were, this large body of water fed from a great drainage area with an abundant food supply moving slowly backwards and forwards with the tide so that the fish and oysters, clams, crabs, and scallops have ample time to feed. We have abused this natural resource very badly, and the problem that faces us is to save it for future generations.

Many difficult problems have arisen. Rights have grown up about these fisheries, on the basis of which people have gained their livelihood, but conservation for the future generations is of just as much importance as the gaining of a livelihood in the present day. Virginia and Maryland have had some difficult problems to solve. The Bay is divided about half way between these states, and the Potomac river is shared in common. We have to arrange our fisheries so as not to interfere with those of Maryland, and Maryland has done the same thing for us. It is along those lines that the present Commissioner of Fisheries in Virginia is striving to make headway; we hope we can so balance the fishing in Virginia as to allow Maryland a chance to get her share, while Maryland on her side will balance her fishing so that the great spawning grounds on the Potomac and the upper part of Chesapeake bay will continue to replenish the supply. It is not at all an easy problem, because the two interests clash at many points, and it takes time, patience and education to achieve the desired result.

SCIENTIFIC FISHERIES WORK IN MARYLAND

R. V. TRUITT

Director, Chesapeake Biological Laboratory

It is a very distinct pleasure for me, sailing with you on this historic bay, to take part in your program and, especially, to discuss before you some of the more important scientific work we are attempting in the fisheries at Maryland's new laboratory on Solomons Island. As director of the Conservation Department's researches, I feel happy over the opportunity I have to work in this very rich, and in many ways nearly virgin region. Opportunities for applied science could barely be better elsewhere than in the Chesapeake bay country.

It is quite commonly held that poets, above all other classes of men, are able, intuitively of course, to picture the hidden, the unknown. When words were given to that well-known jazz song "Sailing Down the Chesapeake Bay" several years ago to the effect that "Every fish and worm begins to wriggle and squirm, when the propeller begins to do the corkscrew turn," the scientists had barely started to explore animal responses and the average man hardly dreamed that at each rotation of the paddle-wheels of a ship, like this we are on, thousands upon thousands of oysters and other mollusks respond by closing their shells and that even greater numbers of crustacea and true fishes become alert and start to hie themselves to safety, while incalculable billions of micro-organisms receive the impulse and set up responses. Today, oysters, for instance, have been electrically contacted and their most secret native activities explored as they have written their own records with kymographic apparatus. Tagged crabs and fishes have yielded much information about their daily life, breeding grounds, longevity, and there has accrued from such efforts valuable knowledge upon which to formulate sound policies for real conservation. Today it is generally recognized that the sea is no longer a "barren vastness," but instead a fertile valley seething with life, in the main uncharted.

When Gray wrote in his celebrated Elegy "Full many a gem of purest ray serene, The dark unfathomed caves of ocean bear," men had not learned to extract iodine, a gem among the elements and a most important therapeutic agent, from sea-weed. Indeed, it was years and years later when this very body of water here began to produce the quantities of oysters Commissioner Earle has referred to, upwards of 20,000,000 bushels in a single year. But it is improbable that Gray had either iodine or oysters in mind when he penned his immortal verses. I like to think he had in mind that

wealth of inorganic and planctonic matter which underlie all life in the water, and with which the Chesapeake is so richly supplied.

I shall not attempt to glorify the State of Maryland before this group, though I confess that it is difficult to refrain from just that when I look toward this west bank and beyond, over fertile agricultural plains and valleys to wooded hills and smoothly chiseled but green mountains, with a thrifty city or town located here and there in the distance, all connected directly to historic Baltimore by fine highways. The Bay here, its banks frequently indented by lovely, broad, salt water rivers, speaks more eloquently for itself than I possibly could. The Eastern Shore you see there, bathed by both ocean and bay, is virtually a garden set in lovely long-needled pine, richly productive of vegetables and truck crops which afford the happiest of homes and family life. Surely Byron could have had that land in mind when he in effect asked in his Bride of Abydos,

> "Know ye the land of the cedar and pine
> Where the flowers ever blossom, the beams ever shine;
> Where the light wings of zephyr, oppressed with perfume,
> Wax faint o'er the gardens of roses in their bloom?
> Where the peach and the melon are fairest of fruit,
> And the voice of the mocking bird never grows mute;
> Where the tints of the earth, and the hues of the sky,
> In color, though varied, in beauty they vie?
> Know ye the land of the cedar and vine,
> Where the flowers ever blossom and the beams ever shine?"

At our new laboratory, a fine brick structure located on a commanding site facing the Patuxent and the Chesapeake, equipped with modern devices and the necessary supplies for the work at hand, we have many and varied problems to attack. In common with the pioneering tendency of all American settlers, early Maryland citizens used wild forms without restraint and a kindly Nature replenished them unfailingly until the on-rush of machines. The Chesapeake stood up until some forty-odd years ago, when depletion of our seafoods set in. The oyster, to cite one case, dropped in production from 17,000,000 bushels in 1885 to 2,000,000 bushels in 1925, or to one-eighth of its one-time abundance, and this at a time when production had increased in most every type of husbandry. It became our problem then to discover, if possible, the causes of such depletion and to work out a procedure whereby it not only could be checked but restoration could be effected.

Oystermen rather generally held that the waters of the state were "dead"; that the oyster beds had been adversely affected by some agency, such as oil, exhaust gas or changes of a physical nature; and that the days of oystering were numbered. Our first step, in attacking this problem, was to make a general survey of the physical condition of the water and to note the biotic relationships. After

several summers sufficient data accrued to make comparisons with records made by that early Johns Hopkins University scholar, Dr. W. K. Brooks (1880-1890), and with the findings of Lt. Richardson, a graduate of the Naval Academy who became interested in biology and did work in our Tangier sound during the eighties. Records of salinity, alkalinity, temperature, and biological forms (numerically), showed no appreciable change in the intervening years except for oysters. In other words, the waters of Maryland, with very minor exceptions, are today as potentially productive of oysters as they were in the days of greatest abundance.

With the knowledge that the Bay, so depleted, is capable of producing as many oysters as it ever did, our problem became one of determining the best method for restoration. Seed oysters were the big problem. How could spat, recently attached oysters, be secured? A series of experiments was set up on the same oyster bed, using shells, pebbles, brickbats, glass and various woods, to ascertain the most efficient oyster gathering materials, taking into consideration cost and availability and power to attract oyster larvae. Oyster shells proved by far to be the best cultch material, exceeding in potentialities the concreted water-proof paper developed by the U. S. Bureau of Fisheries.

Having established that the Bay could be made to produce, and knowing the most effective material for oyster cultch, there remained for us the problem of choosing from the vast areas of depleted oyster bottoms those most rapidly developable. The microscope came into play and all those where no oyster larvae were found (oyster larvae, microscopic in size, swim around in these waters for fifteen to seventeen days, depending upon the temperature) were discarded as far as immediate use was concerned. Only bars where sufficient larvae appeared to assure a "catch" were recommended to Commissioner Earle's department for intensive shell planting. However, full approval was not given any area unless it had been tested out by experiments in shell planting in which wire baskets carrying sixty shells each were used. If sufficient larvae appeared in the water over a given area, and if experimentally planted shells followed up with a catch of young oysters ("spat"), then the area was recommended for development in a big way to the Conservation authorities, who in the meantime had developed a substantial policy for acquiring and planting shells. At present approximately 1,000,000 bushels of shells are being returned to the bottoms annually. The department no longer needs the microscope while choosing areas to be planted. Experience has established that only those sections are developable over or around which sufficient brood stock may be found. Totally barren areas, no matter how productive they may have been once upon a time, are not used.

Our force at Solomons Island working on the oyster problem are attempting experimental work toward the end of developing from

certain barren bottoms, very specially chosen, oyster seed areas. As previously pointed out, the problem of securing seed for private plantings on leased bottoms is our biggest one. Without pointing out the details here, I might say that this investigation, now in its third year, is very promising and we hope soon to have a fine oyster seed bed in the Honga river, the center of our activity.

During the past month we have been experimenting with the breeding habits of the Japanese oyster, *O. gigas,* in an effort to determine whether or not it will cross-breed with the native species *O. virginica.* As you may know, this species from the Orient grows very rapidly, has a fishy smell, is unpleasing to the taste and, with a darkly fringed mantle, is unsightly. We find, in common with experience elsewhere, that it does readily hybridize with the local form. While the poor qualities of this foreign oyster are not so pronounced when it is processed and canned, and it would offer little competition to the east coast oyster when sold fresh, as the bulk of our oysters are sold, it is my opinion that a genuine "yellow peril" would face us if plantings of this species were made in the Chesapeake. In Willipa bay, on the Pacific coast, great quantities of Japanese seed oysters are now being used and, I hear, without bad consequences, since in those waters the temperatures do not rise to a point within its breeding temperature range. This means, of course, that the alien species does not spawn and, therefore, does not mix with the forms native there. Generally speaking, this condition holds in northern waters, here in the East. However, the situation is quite different in the Chesapeake, and southward to the Gulf states, where temperature ranges are around the optimum for Japanese oyster spawning. It is my firm opinion that it would be a very, very big mistake to release Japanse oysters, experimentally or otherwise, along the east coast, not only because of the possibilities of establishing an inferior product, which might readily absorb or replace the native form, but with it accidentally establish a new enemy to do a damage to our water life the equal of or even in greater proportions than that now being done by the Oriental peach moth or the Japanese beetle within our confines.

Crabs, fin-fish, and terrapin likewise have had their ups and downs in the Chesapeake, and they offer problems in many cases not yet attacked scientifically. Just now the Laboratory is busy studying the biology of the blue-crab, a native of this region, which probably will add upward of $2,000,000 in wealth this year to the Chesapeake bay country. This denizen, though having been used for decades, has been so little studied that we do not yet know even its life history, except by inference. Soft crabs are known to all, yet we are unable to tell you how many times a crab molts and becomes soft.

Crabs begin their life in the bay near the ocean. Tiny forms, totally unlike the adult crab, they grow and molt, grow and molt, passing through two distinct larval types of development, the Zoea

and the Megalops, and then for a full year grow and molt in crab form to reach maturity, about fourteen months being required in all. After a few growth stages have passed they start their migration up the bay and reach our shores when they are about one-fourth of an inch in width. Continuing their growing and molting, they reach their adulthood in this section and, taking a leaf from near by Elkton's Maryland's and America's celebrated Gretna Green record, they start their nuptial activities. When crabs mate the male is in the hard shell state and the female in the soft shell state. The male clasps the female just before she molts and swims to a favorable shedding ground, a shallow, grassy, warm area, where she is released to discard her shell. Immediately after becoming soft, the male clasps her and mating takes place and continues for ten or twelve hours, at which time the female's shell has begun to harden again. August and September are the months in which these activities take place for the most part. After mating the female slowly works her way to Virginia waters to overwinter and to lay her eggs during the early summer to follow.

Nearly 75% of the world's blue-crab supply comes from the Chesapeake. Virginia and Maryland possess this resource in common and the problem is a bit confounded by the fact that there exists a lack of accord among their fishermen, as well as the conservationists, relative to vital points in crab life. Virginia just recently permitted the capture of egg bearing crabs, and has permitted from the first dredging of crabs, largely mated females, during the winter season when they are in the stupor of hibernation. Maryland lays down laws that permit of unrestricted fishing except for lower size limit and winter operations. Neither state has a crab sanctuary. Our work indicates fully that both states need crab reserves and that they should be chosen from the most valuable crab fishing grounds known.

Crab studies will be continued at the Laboratory another year in the hope that the full life history of the species, *Callinectes sapidus,* may be known both through rearing them in holding tanks and through observations made in their habitat. Mr. George Beaven, a graduate student at the University of Maryland, will continue this work with me.

Our laboratory building has space for some fifty-odd workers. It has running salt and fresh water in every room, and it is supplied with gas, compressed air and electricity. It has three working floors in it and its furniture was specially made by the Kewaunee people to serve specific purposes. There are six combined office-research rooms, bio-physics and bio-chemistry rooms, a general laboratory for thirty-six persons, a small research laboratory for eight persons, a combined aquarium and museum room, library, lecture room, and rest rooms. The basement floor has a photographic and a dark room, engine room (six electrically driven machines), two store-

rooms, janitor room, dining room, kitchen and pantry or refrigeration room. In fact, the physical plant is just about as complete and satisfactory as those of us who have been working at Solomons island could anticipate, and we are very grateful to the Governor of Maryland and the Commissioner of Conservation for their interest and support in this connection. We trust that we may justify their confidence in making available such quarters for our work.

I would like to go further in telling of Maryland's new laboratory and state that I feel that its mission will be only partially fulfilled if it should deal strictly with research problems, whether pure or applied if there really is a line of demarcation between the two. The serious decline in output of seafoods already referred to would not have taken place, I feel, had the men of the industry and their leaders known long ago the causes of depletion and remedies for them. It is true that they have seemed blind to their faults in some cases, and that they have shown resistance to efforts at rehabilitation on occasions; but are not such attitudes due to lack of information whether here or elsewhere? Indeed, I feel that a very considerable part of this new work should center around the dissemination of knowledge. It is not a hard matter in many cases to unearth new facts, but it may be extremely difficult to put the information into use. There is no better place in our land to illustrate this principle than in your work, members of the Society, for with you science is years and years ahead of practice, as you well know and further realize from the papers at each annual convention.

In connection with our educational program, as well as in research, we have been fortunate in that the University of Maryland, which joined with the Conservation Department over a decade ago in fostering the Chesapeake work, Goucher College, St. John's College, the Johns Hopkins University and Washington College, old and leading colleges in the state, are cooperating in the management and development of the laboratory. These institutions assign members of their staffs to our work and we in turn grant full privileges for their students and staff alike, as far as space permits, without cost. Regular classes are held in the building for which credit, graduate and undergraduate, is given at the University of Maryland. Special emphasis in all this work is placed on local forms and problems. Next year we hope to institute a course in the biology of our more important water forms and offer in it an opportunity for the high school teacher to thoroughly familiarize himself with the conservation of Maryland's water heritage, hoping in turn that this information may be passed on to all parts of the state, city and county alike, so that our citizens may not only take interest in restored productivity but that they may have a genuine pride in a seafood output exceeding by far that grown at the peak of "wild fruit" production. Such a development would bring to this small commonwealth an added increment in wealth sufficient to afford a fine liveli-

hood for more than one hundred thousand people. Such vast possibilities made possible the establishment of our new laboratory. They inspire those of us who are directly responsible for its conduct. We hope to be productive.

Discussion

MR. FOLLETT (Michigan): Were these Japanese oysters planted?

DR. TRUITT (Maryland): We were very careful not to plant them. We held them in salt water tanks in the laboratory and then turned that salt water out on the ground so that no eggs could escape. We take every precaution in that respect, and we hope that others who have them in tanks in New Jersey, New York and Connecticut, will be as careful in that respect.

DR. EMMELINE MOORE (New York): They have been released on the west coast, have they not?

DR. TRUITT: Yes, on the Pacific coast. They bring them across from Japan in shiploads and sell them to planters on the west coast, but the water is so cold that they do not propagate. Incidentally we are not only afraid of the Japanese oyster on the ground that it might eliminate our oyster, or at least weaken its quality, but also that through it some pest might be introduced.

MR. O'MALLEY (Washington, D. C.): The Japanese oyster has spawned on the Pacific coast because they have been picked up by Doctor Hopkins, who has a laboratory at Olympia, near Shelton, Washington, and at Willapa Harbour and Pedilla bay in Puget sound.

DR. TRUITT: I am glad to be corrected by Commissioner O'Malley, but I believe one of your government publications said they did not spawn on the west coast.

MR. O'MALLEY: I know that Doctor Hopkins recently found that they do spawn. I think we were among the first to advise the oyster people on the east coast not to introduce them.

MR. EARLE (Maryland): I might say that on the advice of the United States Bureau of Fisheries we have taken steps to warn everybody concerned in Maryland against the Japanese oyster. We are doing our best to keep them out of the waters of Maryland.

CONSERVATION OF IMMATURE FISH IN OTTER TRAWLING

WILLIAM C. HERRINGTON

Chief Haddock Investigator, U. S. Bureau of Fisheries

The history of the North Atlantic fishery for groundfish dates back to the earliest periods in the history of this country. From these early days the fishery has increased in magnitude until in 1930 more than 320 million pounds of groundfish were landed in North Atlantic ports. The principal types of gear used in the early days were hand lines fished from the vessels or from dories.

Later this gear was largely replaced by line trawls consisting of a long ground line anchored at each end and marked with a flag and buoy. On the ground line were attached a large number of short lines or gangings with a hook fastened to the free end of each. Modern gear of this type carries about 500 hooks to a "tub" and several "tubs" of gear may be set end to end. The line trawls were set and hauled from dories manned by one or two men and the dories in turn were carried by the gallant sailing schooners that brought fame and glory to Gloucester during the period when she ruled as queen of the North Atlantic fishing ports.

In 1905 there took place the first act in a drama which was soon to revolutionize the New England fishing fleet. In that year the steamer SPRAY was constructed at Quincy, Mass., for the Bay State Fishing Company. She was built along the general plans of the British fishing steamers and was equipped for otter trawling. This type of fishing met with a great deal of opposition from the line trawlers who claimed that the otter trawl with its heavy otter boards and ground rope not only killed great numbers of small fish but also ripped up and destroyed the food on the bottom rendering these areas incapable of sustaining the large populations of fish found there in earlier years. Otter trawling for groundfish proved very successful and in spite of vigorous opposition from a part of the members of the industry, the otter-trawl fleet continued to increase until in 1930 there were 323 trawlers of all types employed in the New England fishery.

Following the introduction of the first trawler in 1905 the fleet continued to slowly increase in numbers until about 1925 or 1926 when an innovation in marketing procedure resulted from the filleting of cod and haddock. This greatly expanded the market for these fish and created an increasing demand for haddock which had formerly, to a considerable extent, been avoided by the fleet. A large number of new boats were added to the otter-trawl fleet and others

were converted over from the line-trawl fishery. In 1930 when the otter-trawl fleet had increased to 323 boats the line-trawl fleet had decreased to 115 vessels.

The controversy over the degree of destruction wrought by the otter trawlers on the fishing banks has continued up to the present time. The argument concerning the damage to fish food and habitat caused by dragging the trawls over the bottom has been confined largely to personal opinion as there is little definite evidence either way. We do know, however, that most of the small organisms such as brittlestars, mollusks, crustacea, etc., on which the groundfish feed are sifted through the meshes of the net with little damage.

The small amount of this material retained in the trawl is thrown overboard from the ship when the decks are cleared after each haul, the uninjured members to resume their life as before, and any crushed scallops, mussels, etc., to be eaten by fishes or by animals on which the fishes feed. Fragments of sponges would each begin to grow into a new sponge and mutilated starfishes would soon reproduce the injured or lost parts. The small amount of captured material should, therefore, be little, if any, diverted from the function it would have discharged had it remained unmolested on the sea floor.

As can be seen, the evidence which is available on this question is largely indirect but in general indicates that the damage to the groundfish habitat and food supply is not momentous. In the course of the present study of the haddock fishery, as more precise methods are developed for studying the abundance, distribution and growth rate of this species over a period of years, we shall find it possible to obtain more direct evidence on this question.

The second criticism of the otter trawl as a fishing implement, the destruction of great numbers of undersized fish, has been substantiated by practically every observer connected with the fishery. The magnitude of this destruction, however, usually is not fully appreciated even by the most severe critics of this form of gear. A few hundred or a thousand small haddock weighing one-third to a pound apiece, when scattered about in a haul of several thousand pounds of trash and market fish averaging four or five pounds each become so inconspicuous as to pass with little notice. It is only when their number reaches five to ten times the number of large that their presence attracts comment. Estimates have been calculated for the extent of this destruction of undersized fish. They are based on data collected by Bureau observers from an extensive series of hauls made during sixty-one trips on otter trawlers in 1913 and on measurements and weights collected on trawler trips during the course of the haddock work in 1930 and 1931.

An analysis of these data shows that the proportion of undersized fish in the catch varies with the season, the bank fished and from year to year. Following one or more years of successful spawn-

ing after the fish reach a sufficient size to be held by the nets and are yet too small to be of commercial value, the destruction is enormous; while following poor spawning seasons the destruction is correspondingly less. The sizes subject to this destruction run from about eight inches in length when they are first held by the nets in considerable numbers to sixteen inches in length when commercial size is reached. On Georges Bank these sizes correspond with an age of from about one to three years.

The records discussed above show that in both the 1913 and 1930-31 periods the otter trawlers fishing out of New England ports captured between two and three times as many undersized or trash haddock as marketable haddock. For instance, in 1930 the New England otter trawlers landed approximately 150,000,000 pounds of haddock made up by about 37,000,000 fish. Our field observations and measurements show that in addition to the 37,000,000 haddock brought into market between 70,000,000 and 90,000,000 undersized haddock were taken. Few records are available for other species of fish but such as we have show somewhat similar results. The small fish thus captured are in virtually all cases destroyed as there is very little chance that any should survive after being landed on deck, sorted over and finally thrown overboard.

Since the records cover but two one-year periods, they cannot be accepted as representing the average condition of the fishery. Other data which we have indicate that small haddock were unusually abundant during the two periods considered. These records do show, however, the extensive destruction to which the haddock and cod are subject before commercial size is reached.

Considering the fact that the destructiveness of the otter trawl has been evident since its first introduction into the fishery, it may seem strange that no attempt has been made to modify the gear in order to overcome this characteristic. Probably the principal explanation lies in the fact that practically all of the nets in use here are imported from Europe and usually are replicas of the trawls used there. Once having become accustomed to a certain type of trawl the fisherman's conservation nature has prevented him from attempting modification to permit the escape of small fish, and he has come to consider that the taking of large numbers of small fish is an essential characteristic of the otter trawl.

There is also to be considered the effect of the point of view held by many individuals that the sea is so extensive and the fish population so enormous that any puny inroads which man might make into the supply are negligible; therefore, why be concerned about the destruction of a few million small fish? It is only in the last few years when the fishing fleet has suffered from a marked scarcity of haddock that the folly of this belief in the inexhaustibility of nature has become potent.

During the past few years with their unmistakable evidence of a

growing scarcity of haddock on the principal fishing banks, there has resulted an increasing concern for the future supply. As the fisherman's catch has decreased more and more, in spite of longer trips and greater effort, attention has been, to an ever greater degree, attracted to the loss of millions of pounds of potential market fish through the destruction of the young. This concern finally culminated in 1931 in an agreement among most of the fishing captains to avoid, whenever possible, grounds where small fish predominate. This agreement, however, was not particularly effective as small haddock were rather generally scattered over the fishing grounds on Georges Bank and therefore impossible to avoid without almost complete cessation of fishing.

These developments in the otter-trawl fishery had been followed by the Bureau of Fisheries with particular interest but no study of the problem was possible until funds were provided in 1930 for the study of the haddock, which species makes up the major part of the catch of the otter-trawl fleet. One of the first subjects to receive attention was the problem of youngfish destruction and the development of means by which it might be prevented. Field observations on fishing vessels were begun in the fall of 1930 and field experiments with "savings" gear in May of 1931 following preliminary experiments on the Bureau's research steamer ALBATROSS II.

The primary object of the work has been to develop modifications of the commercial otter trawl that will permit the escape of as large a part as possible of the fish too small to be of commercial use, at the same time avoiding as much as possible any increase in the complexity of design and handling of gear. It is obvious that these two conditions are inseparable as there is little point in developing a highly selective gear if it possesses characteristics that prevent its general use. With this in mind it was found necessary to sacrifice something of the selectivity of the gear in order to obtain a net which would prove practical under ordinary fishing conditions.

European investigators have, as a result of their experiments, developed several types of trawl for the saving of undersized fish, such as the "Ridderstad Savings-trawl," the "Swedish Savings-trawl," and the "Gelder Cod-end." These trawls have given excellent results insofar as the sharpness of selection is concerned; but due to the introduction of rigid metal frames or other complications have apparently been unacceptable to the commercial fisherman and we have been unable to learn of any of this gear in regular commercial use.

A study of the construction of these trawls and the conditions in our fishery has convinced us of the impracticability of attempting to introduce any of them into the American fishery at present. The results of European work also are not directly applicable to our problems for they have been concerned with the saving of fish much smaller in size than in this country. For instance, their haddock are marketable down to about one-third of a pound in weight whereas

the smallest marketable haddock recognized by the New England Fish Exchange is a one and one-half pound fish. Such a fish is on the average about sixteen inches in length.

The study of previous work on the subject as well as preliminary experiments on the ALBATROSS II indicated that the cod-end was the most important part of the trawl for the escapement of small fish. A small percentage may escape through the mesh in the wings, square, belly and belly tops but the major part of the small fish which enter the net eventually reach the cod-end. Consequently, if the cod-end can be constructed so that the undersized fish can escape, the selective action of the remainder of the net becomes of less importance. The experimental work done was, therefore, mainly confined to the cod-end although some conclusions have been reached concerning the other parts of the net.

After the preliminary tests had been completed it was necessary to arrange to continue the work on a commercial vessel as the ALBATROSS II at that time was not equipped to handle commercial otter trawls. Various members of the industry cooperated in the work. The Linen Thread Company and Plymouth Cordage Company furnished most of the experimental gear and the EXETER of the Whitman, Ward and Lee fleet was used for most of the early work through the cooperation of this firm. Later a number of trips were made on the KINGFISHER of the Portland Trawling Company fleet and two cod-ends were made up according to our specifications by the Great Grimsby Coal, Salt and Tanning Company and furnished for our tests.

The first tests of the "savings" gear were made on the EXETER with a trouser cod-end attached to a commercial net. The trouser cod-end consists essentially of two small cod-ends brought together at their upper ends similar to a pair of trouser legs and of such a size that their combined opening fitted the lower end of the commercial net used. A vertical partition was placed in the net extending from the junction of the two cod-ends up the middle of the belly about two-thirds of its length. This arrangement gives in effect two separate trawls fishing simultaneously over the same ground.

In order to test the selective action of any particular arrangement of cod-end mesh or rig, it is used on one leg of the trawl and a cod-end of standard construction on the other. The catch made by the two types of gear can then be compared by measuring all of the fish caught in each leg of the trawl. During the course of the work tens of thousands of these measurements were made at sea under all weather conditions. The trouser cod-end gave very good results, slowed down the fishing operations very little, and was considered on the whole to be the most satisfactory for work on a commercial trawler where the gear must be handled rapidly in order to affect the efficiency of the boat's operation as little as possible.

The results obtained were next applied in the construction of a full-size cod-end for commercial use. This gear gave excellent

results when fished on good bottom but when tried on the rough ground of the "Northern Edge" gave trouble by tearing more easily than the commercial gear. Modifications were made in order to overcome this weakness and a practical design was finally obtained.

A limited amount of work was also done to determine the effect of an increase in the size of mesh used in the forward part of the net; but our most extensive information on this subject has been obtained from Captain William Westerbeke who has since early in 1932 been using large mesh with excellent results on his boat, the VANDAL, fishing out of Boston.

The specific details of the gear as recommended to the industry are of interest primarily to the users and makers of otter trawls and will not be described here. In general, they consist of an increase in the size of mesh used in the top of the cod-end from the present size of about three inches up to five or five and one-quarter inches, and a special construction which helps to keep the mesh open even when subjected to the longitudinal strain on the net while fishing. In the forward part of the net the mesh has been increased to five inches or more. In all cases the measurements are given for stretched mesh.

The methods used in the work have been conditioned by the fact that the field experiments were necessarily conducted on commercial fishing vessels through the cooperation of their owners and crews, and the experimental gear had to be as simplified and practical as possible in order to have a minimum effect on the efficiency of the boat's operation. This very limitation, however, has served to keep ever in mind the necessity that our final gear must be essentially practical in nature if it is to receive the consideration of the fisherman and boat owner.

The practical value of this type of net has been proven by numerous trials of full-sized commercial gear on the KINGFISHER of the Portland Trawling Company fleet under Captain Sylvester Dunn; on the EXETER of the Whitman, Ward and Lee fleet under Captain Martin Pedersen; and also by Captain William Westerbeke from the use of a similar type of net on the VANDAL under Captain Michael Foley. The results of these trials have shown that the new gear is eminently practical. The principal advantages of such a gear are as follows:

1. A large percentage of the undersized haddock, cod and other food fishes destroyed by the present gear is left on the banks to increase the catch in later years when they are of marketable size.
2. The job of landing the trawl and handling the catch is made easier by the elimination of a large part of the small trash.
3. The cost of the net is up to 20% less than the present gear.
4. The nets are easier to mend because of larger mesh and fewer knots.
5. As it offers less resistance, the net can be towed at greater speeds

with the same power now used or at the same speed with less power. This is especially important to the smaller boats when towing against the tide.

As against these many advantages, present experience has shown no appreciable disadvantages when using a properly constructed net.

Discussion

MR. BIRDSEYE (Massachusetts): I just want to give you some of my personal experiences which will bear out the value of the work done by Doctor Herrington. One has to be familiar with the extent of the destruction which results from the use of the ordinary otter-trawl nets to appreciate its tremendous significance. Back in 1929, before the Bureau actively undertook its work, I put a scientifically trained man, who was unprejudiced, on board one of the Whitman Ward and Lee trawlers and he found that, by weight, approximately 30% of all the edible fish brought up in the otter-trawls were killed and thrown overboard as trash. This means that in the Boston trawler fleet alone, something like 50,000,000 pounds of edible fish are thrown away each year.

Of course the edible fish that are so destroyed are not all small; perhaps half of them are thrown away because they are too small, the others because they are perishable or too low priced to be brought ashore profitably. Perhaps the whiting is the fish which best illustrates the latter point. I should guess, and it is purely a guess, that the Boston fleet catches, destroys and throws away at least fifteen million pounds of whiting each year. The whiting is a very excellent fish, but so delicate, so easily bruised and spoiled, and brings such a low price, that the fishermen do not consider it worth saving.

I want to add my testimony, based on a practical experience of at least seven years, to the fact that the work of Doctor Herrington, in making less destructive otter-trawls without sacrificing their efficiency from the commercial point of view, constitutes the highest type of conservation.

THE DEEP WATER TRAP NET AND ITS RELATION TO THE GREAT LAKES FISHERIES

FRED A. WESTERMAN

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No question within recent years has caused so much concern alike to commercial fishermen and to conservation officials charged with administering the commercial fisheries of the upper Great lakes, particularly Huron and Michigan, as has followed the introduction of the deep water trap net within the past few years.

Let us consider the construction of these nets in order that we may better understand their operation. The dimensions vary considerably to suit the conditions where they are to be fished or the individual fancy of the operator. A typical net may be considered as having the pot thirty feet deep, thirty-six feet long, and twenty-four feet wide; the wings forty-five deep and 100 feet long; the lead forty-five feet deep and 1,500 feet long. The mesh in the sides, top, bottom, front, and back of the pot varies from three and one-half to five inches, with the side of the pot where the fish are shoaled usually of finer mesh; wings from four to seven inches and lead from five to nine inches.

As the name implies, these trap nets are designed for deep water fishing. They are set entirely without stakes, being held in place with anchors, and fitted with buoys and sinkers of iron or chain. They have the advantage of mobility, as they can be moved and reset with comparative quickness and ease. Some lake trout are taken in these nets but they are primarily a whitefish net. One leading manufacturer advises: "The construction of deep trap nets should be as open as possible; that is, the mesh should be large and the twine comparatively light. Shadows should be avoided, and care should be taken in setting so that the net is properly spread laterally to prevent the pot from swaying and thus closing the mouth of the funnel. Mesh in the pot should be as large as possible to prevent taking small fish."

These nets are usually hung on the one-third basis, that is, eighteen inches of stretched netting to twelve inches on the lines. They are in effect pound nets, the principal difference being that the funnel and pot in the trap net, which corresponds to the heart and pot in the pound net, is covered with netting. Also in freeing pound nets, the fish are cornered at either side or the back of the net and dipped out with small hand nets directly from the open net, while in trap nets the pot must be brought to the surface and the fish dipped out through an opening usually in one side or the back which is laced up before re-setting.

This net is of course very similar to the pound net in use for many years which is held in place by means of stakes but which is limited, however, by the length of the stakes which can be used and the character of the bottom where stakes can be driven and held. Some pound nets are set in eighty feet of water but the great majority are set in less than sixty feet and where a stakeless trap net can be set in about five hours under favorable conditions, it requires about two days to set the pound net. An important difference occurs in the fact that whereas the lead of pound nets rarely reaches thirty-five feet in depth, stakeless trap nets are reported in use with leads up to seventy-five feet in depth; in other words, a wall or fence of netting seventy-five feet high and 1,500 feet long for leading the fish into the pot or trap which may be sixty feet high.

That the trap net can be set and lifted at any depth and on any kind of bottom is too broad a statement. There is a maximum depth in which this net can be fished. In Wisconsin, they have been fished in one hundred feet of water and in Michigan, they have been set in depths of one hundred sixty feet. Although trap nets have been set on a rocky bottom, it is not profitable to do so since the chafing of ropes and netting on the rock soon wears them out. Trap nets, like pound nets, are therefore set on sandy, gravelly, or muddy bottom. However, since the stakes of pound nets must be driven eight or ten feet into the bottom, all soft bottom, even though underlaid with rock, may be suitable for trap nets, but not for pound nets.

A Lake Huron fisherman comments: "To fish deep trap nets satisfactorily, it is necessary that the water have a depth of twenty-two fathoms, also to get away from small-sized fish."

These depths of course are much less than the depth at which gill nets are fished for whitefish but their adoption by many fishermen has tremendously expanded the field in which trap nets operate and brought them into keen competition with the gill netters. In fact, trap nets appear to be comparatively much more efficient where set in proximity to gill nets. It has been reported that gill nets set in the same locality as the deep trap nets will not take whitefish to any extent while the trap nets will take large catches of unusually large fish, a size of whitefish which the four and one-half or five inch mesh gill nets have not been able to catch because they are to a degree selective gear; that is, they will not take undersized whitefish or the unusually large fish in any great numbers since the small fish pass through the net and the large fish cannot become gilled in it.

Gill nets are limited in Michigan by statute to eleven feet as the maximum depth and to four and one-half inches as the minimum size of mesh for taking whitefish and trout; in actual practice they seldom exceed twenty meshes or seven and one-half feet in depth.

It is reported from numerous localities where deep trap nets are employed that these nets are responsible for the killing of many thousands of undersized whitefish. This is believed due to the in-

ability of the fish to adjust themselves to the difference in pressure when the nets are quickly lifted and brought to the surface and to injury resulting from the handling incident to sorting the fish, perhaps also to the nets being left too long before lifting. It is reported these nets have been set for months during the winter season without lifting, but this condition is not confined to the deep trap nets alone as many gill nets are lost annually through being carried away by storms following a freeze-up during a cold snap, which prevented their being lifted or removed by the fishermen. This is principally due to weather conditions rather than neglect and represents a severe loss to the fisherman which is not the case with the deep water trap net.

The deep water trap nets appear to have been used first in Lake Ontario, where according to Mr. J. P. Snyder, Superintendent of the U. S. Bureau of Fisheries Station, Cape Vincent, New York, they "cleaned" up the pike and whitefish at Cape Vincent and in Chaumont bay. I quote him briefly: "Two or three men could hardly move and reset a pound net in a couple days, but the same crew will change the position of half a dozen trap nets in a day. It is this mobility and the fact that they can be set in any depth of water, even to a hundred feet or more, that makes them so effective."

The first of these nets was introduced into Lake Huron at Alpena in 1928 by one of the Cape Vincent fishermen. His large catches reported running as high as two thousand dollars worth of fish a week, immediately attracted attention and of course the adoption and extension of their use by other fishermen, first at this port and then spreading until at present they are widely used in Lake Huron, Saginaw bay, Upper Lake Michigan and to a lesser degree in the eastern part of Lake Superior. This spread has been more rapid since 1931 when the Michigan legislature failed to deal with the problem. Many fishermen, even though opposed to their use, adopted them in order to meet the competition of their neighbors. The fear persists that the whitefish, which is generally conceded first rank in quality among the fishes of the great lakes, is doomed unless measures are quickly adopted to regulate and restrict the use of this gear.

Recently our department submitted a questionnaire to commercial fishermen licensed to fish in Michigan waters, enabling them to register their views with reference to existing regulations and changes they believe should be made. Replies have been received from 494, a return of about 40%. Of these, 296 made no reference to the deep trap net, 142 registered their disapproval, and only thirty-two fishermen favored their use. From our records we find that there are over 2,700 shallow water trap nets and 461 deep water trap nets owned by Michigan fishermen at the present time. A note indicative of the feeling among many fishermen, was received with an application for a license, which reads as follows:

"If (deep water) trap nets are not outlawed, fishing in Lake Huron

will be history in five years. This boat is for deep traps, but we would gladly quit, if they were outlawed."

The Michigan Department of Conservation as early as 1930 sounded a warning to the fishermen against adopting this gear and later the same year, the U. S. Bureau of Fisheries protested their use in part as follows: "If this destructive method of fishing is to continue, the commercial species of the great lakes will soon be depleted."

The U. S. Bureau of Fisheries has been making exhaustive investigations of many problems confronting the commercial fishing industry on the Great lakes during the past several years, including a study of the deep trap net question, which was begun in 1931, in cooperation with the states of Wisconsin and Michigan.

A report was prepared for the Wisconsin Conservation Commission by Dr. John Van Oosten, U. S. Bureau of Fisheries; B. O. Webster, Superintendent of State Fisheries, and Ira G. Smith, Conservation Warden, which provides some interesting deductions. This committee found that the deep trap net is not more efficient than the pound nets fished in the waters off Door county, when fished in waters of the same depth. The advantage of the stakeless trap net is considered due to the fact that they fished waters where the whitefish were most abundant in May and June, that is, just outside the reach of the shallow pound nets in about fifty feet of water. A comparison of the average number of pounds of whitefish per lift per net taken in the two kinds of gear off Door county, Wisconsin, is provided in Table 1.

TABLE 1

Year	Nets	Average Pounds of Whitefish per Lift per Net		
		May	June	May and June
1930	Pound nets	88.4	143.7	126.7
1931	Pound nets	85.1	169.7	136.4
1931	Deep trap nets	228	376.4	315.3

"On the average the deep trap net took about 2.4 times as many whitefish per lift as did the pound nets. These data corroborate the statements of both poundnetters and trapnetters that deep trap nets catch more fish than shallow pound nets. As explained above, this is almost entirely due to the fishing of the trap nets in deeper water"—to quote from the report. Table 2 provides a comparison of the catch of whitefish of four shallow pound nets and of two deep pound nets and of several deep trap nets fished in Door county waters in June, 1931:

TABLE 2

	No. of Lifts	Whitefish lbs.	Trout lbs.	Average Lift Per Net Whitefish lbs.	Trout lbs.
Shallow pound nets	58	2,566	241	44.2	4.2
Deep pound nets	60	21,861	890	364.3	14.8
Deep trap nets	184	69,359	2,334	376.4	12.6

"The data of this table show that the average lift of whitefish of deep pound nets far exceeds (8.3 times as great) that of the shallow pound net and approximates that of the deep trap nets. These data support then the assertions of those fishermen who claim that deep pound nets will fish as well as deep trap nets and that the increased catch of deep trap nets over that of shallow pound nets is due entirely to the fishing of the former in deeper waters."

To quote again: "There are certain other considerations that must be taken into account. Abolishing the trap nets will not eliminate these nets from Door county. Some of the trapnetters have already ordered stakes and will on a moment's notice convert the deep trap nets to deep pound nets by bringing the pot to the top of the water and anchoring a few stakes to it. We feel certain that if the deep trap nets are abolished, the residents of Door county will build deep pound nets now that the trapnetters have shown them that their pound nets are too shallow. All fishermen, whether poundnetters, gillnetters, or trapnetters, are after fish! The investigating committee believes that the deep trap nets should be regulated and not abolished."

In Table 3 is presented a general summary of the data on certain deep trap net investigations made by Dr. Van Oosten in Lakes Huron and Michigan in the summer of 1931:

TABLE 3

Depth of water	No. of lifts	Ave. No. of fish per lift (legal and illegal)	Ave. No. of legal fish per lift	Per cent of legal fish per lift	Ave. No. of illegal fish per lift	Per cent of illegal fish per lift	Number of Nets
60 feet and less	16	78.3	25.6	32.7%	52.7	67.3%	16
80 feet and less	59	88.1	45.3	51.4%	42.8	48.6%	54
100 feet and less (Incl. 8 lifts at 100 feet)	88	140.7	75.1	53.4%	65.6	46.6%	(incl. 7 nets at 100 ft.) 80
100 feet and deeper (Incl. 8 lifts at 100 feet)	56	238.7	183.8	77.0%	59.4	23.0%	(incl. 7 nets at 100 ft.) 45
Deeper than 100 feet (Exc. 8 lifts at 100 feet)	48	230.6	184.5	80.0%	46.1	20.0%	(excl. 7 nets at 100 ft.) 38
61-80 feet (incl.)	43	91.7	52.6	57.4%	39.1	42.6%	(incl. 7 nets at 100 ft.) 38
81-100 feet (incl.)	29	248.0	135.8	54.8%	112.2	45.2%	26
101-105 feet (incl.)	16	266.1	187.6	70.5%	78.5	29.5%	14
106-109 feet (incl.)	5	98.0	74.8	76.3%	23.2	23.7%	5
110 feet and deeper	27	223.0	191.9	86.1%	31.1	13.9%	19

I quote from his recent letter accompanying this table:

"A study of this table will probably show that in order to protect legal whitefish, fishing should be confined to eighty feet and less. This might apply to most of the ports. It would, however, not apply to Alpena. In order to protect illegal fish, fishing of the deep trap nets

should be conducted in 110 feet and more. The illegal whitefish appear to be most abundant between 80 and 105 feet. If recommendations are made to prohibit deep trap nets in water deeper than eighty feet, the trap nets will be concentrated in the bays. In that case, it will be necessary to regulate the distance between nets or strings as well as the size of mesh. I am of the opinion that the distance between nets should be at least one-half mile, that the size of the mesh should be not less than four and one-half inches as fished. I believe that a five-inch mesh would be better but it would not be fair to ask the trapnetters to use a five-inch mesh while the gillnetters are allowed a four and one-half inch mesh. From the 1931 data, it appears to be a question as to whether we should save the legal or the illegal fish."

This has reference to the investigations made last year, when many excellent catches of whitefish resulted. Deep trapnetters probably were to a large degree responsible for the catch of whitefish exceeding all other species of fish taken from Michigan waters for the years 1929, 1930 and 1931—a condition which did not previously prevail for many years, but who can say at what a cost, for, since then, the catch has rapidly declined in several localities. Listen to Dr. Van Oosten's summary conveyed to me in a very recent letter:

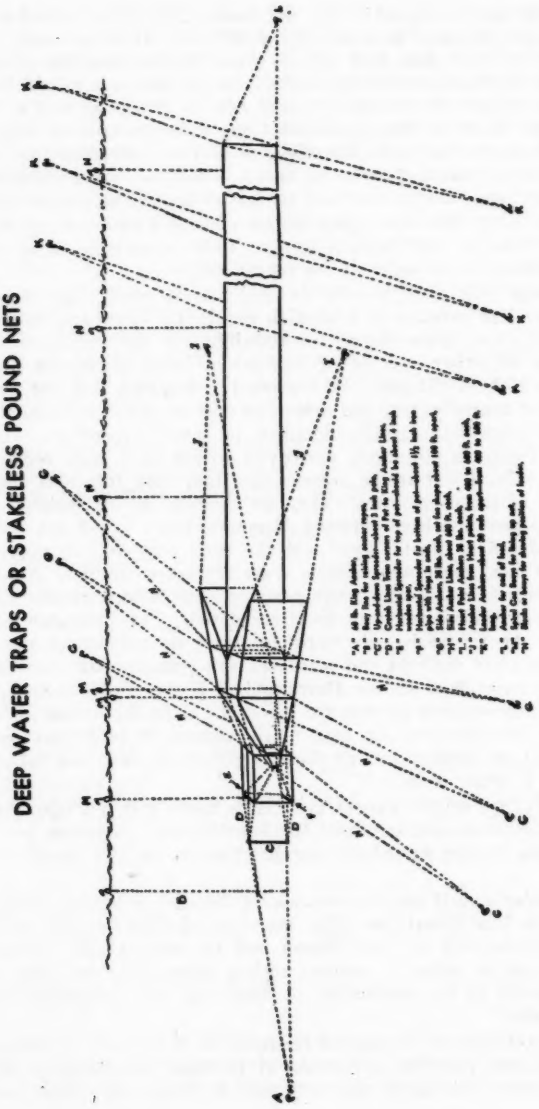
"Personally, I feel at the present time that deep trap nets should be kept out of the deep water. They are cleaning up the whitefish population. Alpena has been depleted, Hammond's bay fished out, fishing is much reduced at East Tawas and the deep trap nets in upper Lake Michigan must move westward in order to secure big lifts. Apparently the grounds fished in past years have been depleted, certainly the lifts on these grounds have been greatly reduced. The fishermen will tell you that the whitefish have migrated, but I do not believe this. The old grounds are depleted and whenever new grounds have been opened up, as for example at Harbor Beach and off Scott's Point in upper Lake Michigan, tremendous catches are reported. Even the fishing in Whitefish bay, Lake Superior, has been much reduced. It would seem peculiar to me that the whitefish of all these territories in the three lakes have migrated to other grounds."

Naturally, we might expect criticisms from gill net operators, but the complaints are not confined to them alone. One trap net operator on Lake Huron in submitting his report for the month of May writes:

"*No production.* If the continuation of deep sub-fishing is allowed, it will not be long before the daily report of all fisheries on the Great lakes and especially on Lake Huron, will be such as this. Immediate action should be taken to prevent such a catastrophe and this action should consist in the elimination of deep trap nets commonly known as deep subs."

The despoilation of a natural resource to the point of commercial exhaustion, and possible extinction if pursued far enough; with its attendant losses, hardship and suffering to those who look to it for

DEEP WATER TRAPS OR STAKELESS POUND NETS



a livelihood, presents to me a tragic picture. Whereas, if our fisheries can be properly controlled and regulated they should continue to furnish a never failing supply. It is a serious arraignment of a system which does not have power or authority to immediately deal with its problems. Deep trap nets seem to have invaded the sanctuary of the whitefish and, with the present size of mesh fished in unlimited depths, are depleting the mature fish and destroying the juveniles.

This gear, if properly regulated, would seem to be very efficient, and I believe, may be considered as having a place among the various types of equipment in common use to meet the varying conditions encountered on the Great lakes. I have every sympathy with the commercial fisherman and the hardy, rugged existence he leads, but as I have said many times, it must be somebody's business to look after the welfare of the fish. Any decision as to what regulations should be imposed must necessarily be more or less arbitrary.

I agree fully with my friend, Dr. Van Oosten, that size of mesh in the pot and restricting both the depth of water in which they shall be set and the proximity of the nets in relation to each other must be adopted. I believe the size of the mesh for taking whitefish and trout should not be less than four and three-quarters inches and preferably five inches as fished, and that the depth of water where these nets shall be set, should be limited to not more than seventy feet. Very probably the same restrictions should apply to pound nets for in reality they are essentially alike.

I am indebted to the Honorable Lewis Radcliffe, Deputy Commissioner, Dr. John Van Oosten, and J. P. Snyder of the U. S. Bureau of Fisheries; the Wisconsin Conservation Department; the Honorable William H. Loutit, Captain C. J. Allers and the Staff of the Michigan Conservation Department and many commercial fishermen for data and material used in the preparation of this paper.

Discussion

DR. VAN OOSTEN (Michigan): I may say that the investigation of deep trap nets is still under way and that we expect to conclude it some time in October. I do not know whether you realize the significance of the introduction of the deep trap net into the upper Great lakes in 1928, as brought out so well in Mr. Westerman's paper. In Lake Erie the regular trap net has the following dimensions: nine feet wide, nine feet deep, and twelve to thirteen feet long. The deep trap net which is now being introduced is thirty-six feet deep by twenty-four feet wide and thirty-six feet long. The fact that in one instance one single trap net has taken a lift of whitefish of 5,200 pounds, will give you some idea of what damage the deep trap net can do.

SCIENTIFIC METHODS OF OYSTER FARMING

HERBERT F. PRYTHERCH

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The oyster industry of the United States is the greatest in the world; it represents the largest development in the field of aquiculture. In the cultivation and harvesting of oysters, considerable capital is invested, and there is involved a large expenditure of funds in connection with the cultural operations. It is necessary that we learn as much as possible about the oyster and its environment in order that these operations may be carried on efficiently. Studies along this line have been carried on by the Bureau of Fisheries at various stations on both the east and the west coast.

Our marine aquatic products represent in some degree a development or growth of marine animals which is brought about by substances brought down from the land. In the case of the oyster, we find our oyster beds storing up many valuable land elements. We hear a great deal about the loss of valuable land constituents, from erosion; our oysters and other shell fish reclaim a large amount of this valuable material. In the oyster there is a large amount of copper, iron, iodine and other important mineral salts, the value of which is recognized in nutrition.

In the South Atlantic region the oysters thrive chiefly in the harbors and bays and mouths of the rivers. Market size is attained in about three or four years in Virginia waters, in four or five in the north, and in about two in the South Atlantic region.

During the summer months the oysters produce within the body a very large number of eggs. When the water warms in the early summer months the oysters are induced to spawn by the increase in the water temperature, as it approaches about twenty degrees centigrade. The male oysters spawn first. Interesting studies conducted by Dr. Galtsoff show that the spawn from the male oyster stimulates the spawning of the female, and in the commercial operations this means that it is necessary to have the oysters fairly close together on the natural spawning beds in order to ensure fertilization of the egg.

In the spawning of the female oyster the shell or valves are vigorously brought together, and with each convulsion a cloud of eggs is discharged into the water. The spawning lasts usually from about half an hour to an hour.

A continuous stream of water flows from the right side of the oyster whenever it is feeding. In the male oyster the spermatozoa are released into this stream of water and carried out of the shell. Studies made by the U. S. Bureau of Fisheries show that an oyster

drinks approximately eighteen to twenty gallons of water a day during the summer months. On one occasion I estimated the amount taken in by the oysters on one of the natural beds in Virginia, and it was something like seventy-five times as much water as is used daily in the City of Philadelphia. The studies of the "drinking" of the oyster are applied in commercial operations to obtain fat oysters. On account of the water demand of each oyster, they must not be planted too close together, otherwise they might not get sufficient food and oxygen.

The oyster egg as it is discharged in the water is more or less pear-shaped and later becomes rounded. The egg, of course, is soon fertilized, and surrounded by a fertilization membrane. It is a simple matter to take the spawn from the oyster and cross fertilize them in small dishes. Studies of this sort were made in connection with the Japanese oyster. By crossing the spawn from both species it was found that fertilization did occur. None of the larvae from that crossing were carried through to maturity or to the seed oyster stage, so we do not know what sort of oyster we might obtain.

As the single cell resolves into the two-cell stage, in about one-half hour, there is a rather remarkable phenomenon. Some of the protoplasm of the egg apparently flows out and goes through a twisting performance and then draws back into the egg. Apparently there is no explanation for this in our present knowledge of egg cell division.

The eggs are extremely small, measuring about one-five hundredth of an inch in diameter. Because of their small size it has always been difficult to carry out any method of artificial propagation of the oyster. That is quite unnecessary, though, as we have found with our experiments in Connecticut that, if spawning beds were established, the spawn from the oysters would stay within fairly close proximity to these beds, and that by placing seed collectors on these beds we could get a much greater seed supply than could be obtained by artificial methods of propagation.

In about two and a half hours the egg is developed to what we call the larval stage, and by means of delicate, hair-like structures, cilia, the small larva is able to swim about in the water and gather food.

In studying the distribution of the oyster larvae and their apparent development we use very fine silk nets of bolting silk. We collect, of course, larvae of numerous bivalve species, but we can always distinguish the oyster larvae by this hump which protrudes from the left valve. It has been estimated that during the first two weeks oyster larvae increase in volume about one hundred and twenty-five times.

It was found in Connecticut in connection with the studies of the veliger larvae that they were able to offset the seaward movement of the water with the tides by dropping to the bottom. They would drop to the bottom during certain tidal stages and even remain upon

spawning beds located at the mouths of rather swift moving rivers.

When the larva is about two weeks old it reaches the most critical stage in its existence, and it must attach itself to some submerged structure in order to survive. In 1927-28 I endeavored to find out how the oyster was able to attach itself and what natural conditions produced the set. After a year of rather discouraging results I contaminated the water with copper and, upon looking at larvae under the microscope, I found they were behaving in a rather peculiar manner and were actually preparing to attach themselves to the dish. Subsequent studies have shown that the presence of copper in the water is necessary to stimulate the attachment of the larval oyster.

After receiving the copper, we find a protrusion of the foot by which this more or less clamlike animal is able to crawl about on any surface with which it comes in contact. When it receives a small amount of copper it releases a very fine, sticky material by which it becomes attached to shell or stone or any object with which it may come in contact. After about fifteen or twenty minutes the larva has ceased the crawling phase and is about ready to cement itself to the surface. The shell is held firmly in that cementing fluid, and in about sixty seconds it is so firmly attached that you cannot dislodge it by vigorous washing. From this time on the oyster loses its ability to move of its own volition. Studies were made to determine how long it took the oyster larva to attach in water of different degrees of salinity, and we found that the optimum salinity was around fifteen to twenty parts per thousand. If the water were very salt or very fresh, the larvae would fail to cement themselves to the side of the dish.

In Connecticut certain areas are valuable or desirable for collecting seed oysters. These areas lie in the zones in which the water has the highest copper content. At certain stages of the tide, particularly the low water stages, there is more river discharge and more copper present, and the exposed flats are utilized for collecting seed oysters. We use on these areas a variety of devices to collect as many seed oysters as possible.

It was found that in order to obtain metamorphosis from the larval to the spat or seed oyster stage they had to have an additional amount of copper. When placed under natural conditions so that they could obtain more of the colloidal copper material they metamorphosed in about eighteen hours. Those that were kept in dishes in high tide water which contained practically no copper did not metamorphose until they were given an additional supply of water containing copper. There is in the blood of the oyster a use of copper in its oxygen carrying function much the same as iron is used in our own blood. If the larvae are kept in aquaria supplied with high tide water, which contains very little copper, they gradually become weak, are attacked by protozoa and are destroyed.

In order to collect as large a number of seed oysters as possible on the tidal flats, the Bureau developed a particular type of seed oyster collector. We planted 7,000 of these collectors on five acres of bottom and gathered 20,000,000 seed oysters. If oyster shells are thrown overboard we lose from 50% to 90% of the spat from overcrowding. By means of this method of collecting we can save at least 30% which would otherwise be lost.

The oysters in North Carolina last summer, where we made some experiments, did not spawn until the last of August. Previously it was generally believed that spawning occurred early in southern waters. Here providing size limits on oysters taken for market results in preserving the natural bed. The culling of the oysters is done from the bottoms from which they are collected, and the old shells and unused oysters are left there for the next season. If it were not for this type of regulation, many of the beds in Chesapeake bay and the southern states would have been destroyed long ago.

Discussion

PRESIDENT RODD (Canada): Would you tell us, Dr. Prytherch, what type of spat collector you have found most efficient, and how it is constructed?

DR. PRYTHERCH: You can hardly say that one particular type of spat collector is the most efficient in general. Each particular locality has problems that are peculiar to its waters. The most efficient collector in southern waters is the brush and the old shells. In the northern waters we have found that by using old oyster shells, placing them in wire bags, we could build up an amount of surface for a particular area of bottom about ten times and thus save many seed oysters that would otherwise be lost. At the present time the cheapest collector is oyster shells, but it does not produce as good a quality of seed.

PRESIDENT RODD: Are you using the compartment container type?

DR. PRYTHERCH: The egg crate collector is used primarily in the north where the seed oysters are more valuable. The seed oysters we get down south for five or six cents a bushel, cost $1.50 in the north.

MR. MARKUS (New York): After the oysters are culled do those below legal size become attached again, when returned to the waters.

DR. PRYTHERCH: No, the oyster after it is first attached as larva is never attached again.

MR. EARLE (Maryland): In connection with catching spat I may say that we have obtained excellent results in Maryland. In order not to lose the young spat that has become attached we run our shells through the packing house and then if the water is not too cold we take the shells back to the growing bottoms. In some localities in Maryland you can find spat of three distinct years on the shells, and if we throw these shells out we would be wasting thousands of bushels of oysters. We adopted this method after noting the tremendous waste that was being incurred in oyster shell piles.

COMBATING THE STARFISH MENACE ON MASSACHUSETTS SHELLFISH GROUNDS

RAYMOND J. KENNEY

Director, Division of Fisheries and Game, Massachusetts Department of Conservation

Occasionally a state fisheries department is suddenly confronted with a major problem affecting some branch of its work, the seriousness of which almost approaches a calamity; and though it calls for immediate action, yet for the solution of it no precedent has been established. Such a situation arose in the latter part of 1931 in the Marine Section of the Division of Fisheries and Game in Massachusetts, when the alarming inroads of immense numbers of starfish threatened to wipe out the scallop fishery along the shores of Buzzards bay and Vineyard sound.

To adequately appreciate the situation, picture to yourself an industry with a normal potential value of $2,000,000 spread out along a coastline of more than 100 miles, furnishing a livelihood to over 1,200 fishermen and with a market near at hand capable of absorbing more than the entire output. Such was the status of the scallop fishery of Massachusetts prior to 1929. Then over a period of little more than two years the yield of this industry rapidly decreased to $600,000, and our statistical department predicts for the season of 1932-3 a further decline to about $300,000.

Furthermore, this decline was not the result of overfishing, as is usually the case, for it occurred in spite of exceptionally good sets of seed and with weather conditions favorable both for fishing and for the growth of the shellfish. The quite obvious cause was the scallop's natural enemy, the starfish; for, in addition to the abundance of "stars" brought up in the dredges, there were many freshly emptied scallop shells with the uninjured valves still fastened together and often with the starfish still attached.

The towns along whose shore lines this industry exists, and which are responsible under the state law for the major part of its protection, were not able, unassisted, to adequately combat this menace although they expended thousands of dollars in a more or less futile effort. The quantity of starfish invading the scallop grounds was so great that one town in a single day spent an appropriation of $1,000 in the purchase of starfish from the fishermen at one dollar per bushel. A second appropriation by the same town was exhausted at a lower rate in three and one-half days. One fisherman alone caught eighty-eight bushels of starfish in one day. This amount represents approximately 26,400 individual stars. No small part of

the difficulty encountered by the towns was due to the presence of large beds of starfish in the waters of neighboring towns in which, either the industry was not deemed important enough to warrant an appropriation to combat the starfish, or the seriousness of the menace was underestimated.

Such was the condition when, in the latter part of 1931, our biological department, supporting the local shellfish leaders, called attention to the need of state assistance. This was deemed necessary not merely to supply additional financial aid to the towns, but also to give uniform direction to the efforts. Never was there a time when need of assistance came at a more inopportune time. In the effort to effect economy in all state projects appropriations were being pared to the bone, and departments were called upon to justify even their regular expenditures.

However, an appropriation of $15,000 (considerably under the amount asked), was secured and its expenditure placed under the control of the Division of Fisheries and Game as an aid to the several towns in the vicinity of Buzzards bay where the menace was greatest. In order to secure state aid each town was required by law to appropriate and spend a certain amount for starfish suppression. It would then be entitled to a maximum of three times that amount from state funds to be expended under the direction of the division. The unfortunate part of the program was, that the appropriation did not become available until most of the starfish had spawned and the water was filled with billions of larval starfish which were being carried by the currents of water to every little cove and inlet.

Immediately upon the passage of the budget our Supervisor of Marine Fisheries called a conference of the selectmen of the towns principally affected, and a plan of action was agreed upon.

It was decided to spend the state funds exclusively for the purchase of starfish on a per bushel basis through a voucher system, checked by both state and town officers, and to place the expense of collection and disposal upon the towns. Profiting by the experience gained by the individual towns a moderate price of twenty-five cents per bushel was decided upon, although later, in certain localities where the greater distance of the beds from shore made the trip unprofitable for the fishermen, the price was increased to thirty-five cents.

One of the first things demanded of the towns was to require the fishermen, under penalty of revoking their permits, to bring ashore all starfish caught by them when dredging for scallops. This was made all the more necessary by the absence of a state law to that effect. Many towns had already seen the advisability of such a regulation.

In prosecuting this work the state has been practically without a precedent. To be sure, commercial firms had for years sought relief from starfish by dragging over their oyster beds cotton tangles or "mops" to which the starfish would cling, and, rather recently,

the U. S. Bureau of Fisheries had advocated the use of copper sulphate for oyster beds which had become heavily infested with starfish. But the use of copper sulphate, not thoroughly justified at any time from a biological standpoint as a conservation practice, except as an emergency measure in limited areas, was decidedly impractical in the present situation because it is almost as toxic to the scallops as to the starfish. Furthermore, the cotton tangles were not practical because the boats of the fishermen were not equipped to operate them successfully and they were unnecessarily slow for taking such quantities of stars. The small scallop dredge appeared to be the instrument best adapted for the work as they were carried by all fishing boats as a regular equipment.

The division was further handicapped by the lack of accurate knowledge of the migratory habits of the starfish. When the work was started in July the fishermen made the rather disheartening discovery that the starfish were not to be found in the large quantities expected. The catches were very small and quite unsatisfactory from a remunerative standpoint. An investigation was consequently made by the division and it was learned that the bulk of the starfish had moved offshore into deeper water. An area of great abundance, comprising about four square miles, was found in the vicinity of Cleveland's Ledge in Buzzards bay in a depth of twenty feet of water. The starfish in this area were large and the very surprising fact was observed that more than 10% of them had not finished spawning. After a day or two spent in determining the limits of the bed, the fishermen were notified, and in six weeks' time, which was interspersed with stormy weather, more than 4,000 bushels of stars had been taken. At the usual average of 300 stars per bushel this amount represents approximately one and one-quarter millions of individual stars. As each of these is easily capable of consuming more than two adult scallops per week, the total number of stars already taken from this area would consume, in a year, more than 125,000,000 adult scallops, equal to 425,000 bushels. A very much larger quantity of the smaller "seed" scallops would have been consumed had they come in contact with them.

A few other and smaller areas of abundance have been located which have not as yet been exploited by the fishermen. With the coming of cooler weather the starfish will undoubtedly move back into the shoaler areas, and, as is their usual custom, mat together in large patches. At this time they can be caught in very much larger quantities, but the division has been working on the theory that every starfish taken will to that extent lessen the menace to the scallop beds.

Our marine biologist, Mr. Ernest W. Barnes, has been very largely responsible for the success of this work and he has devoted his talents and efforts unsparingly to master this difficult problem. I wish that he were here today to tell you of a number of interesting facts

and problems which have been noted in the very short time that this work has been under way.

There is an apparent migration of starfish during the warm weather to the deeper and cooler areas and a return to the shoal areas during the cooler weather. The tendency of the starfish to frequent rocky and trash-covered areas during the warm weather presents an unusually difficult problem because it is quite impossible to dredge them in these areas. Traps or pots are being experimented with for special use in such localities. An unexpectedly large number of starfish were found to be recovering from the loss of one or more arms. This was a rather interesting finding, the significance of which is not yet apparent. A large amount of ripe spawn was present as late as the end of July. This indicates that the starfish has a long spawning season.

It was observed that a very large percentage of starfish become visible as set—one-sixteenth inch in diameter—by the middle of July, which is just in advance of the appearance of the scallop set. This fact is of very great import, as the young starfish are thus enabled to do very great damage to the scallop set.

The problem of ridding large areas of starfish is a tremendous one and the possibility of doing it with 100% efficiency is beyond our fondest hopes. The immense amount of spawn thrown out by the starfish (from five to ten million per individual), the rapidity of their growth, the almost entire lack of natural enemies, the fact that they attack scallops even in the larval stages, their rapid recovery from major injuries which lessens the chance of death—all of these facts make the task an almost hopeless one. Nevertheless we believe that by systematic work, intelligently directed, the damage may be reduced to very small proportions.

Only a few towns are at present cooperating with the state in this work, and indeed one of the problems of the division is to awaken the various localities to a proper realization of the importance of suppressing the starfish. Recently we have been encouraged by the interest shown by certain towns which at first minimized the importance of the project in their particular localities.

Thus, we have overcome the obstacles which we faced in seeking a solution of this very serious problem, and I believe our efforts up to date will have a beneficial effect in restoring our highly important scallop fishery. If our experiences are of value to you in the problems which confront you, we beg to be of service.

Discussion

MR. SWEPSON EARLE (Maryland): May I ask Mr. Kenney whether the use of copper sulphate for the destruction of starfish has had any bad effects on the oysters?

MR. KENNEY: So far as I know, it has not been used to a sufficient extent in the oyster regions to enable us to have any definite knowledge. In fact, the use in Massachusetts has been very limited to date.

PROBABLE INFLUENCE OF QUICK-FREEZING ON THE SHELLFISH INDUSTRIES

CLARENCE BIRDSEYE

Director, The Birdseye Laboratories, Gloucester, Massachusetts

It is not necessary to include in this paper a detailed description of the process of "quick-freezing" as compared with "slow" or "sharp" freezing. It is enough to point out that quick-frozen flesh products are frozen with such extreme rapidity, usually by contact with cold liquids, fogs, or refrigerated metal plates, that a minimum of damage is caused to their tissue structure.

Although quick-freezing is now being applied to considerably more than 100 different kinds of meats, poultry, fruits, and vegetables, it was first commercially developed in connection with the preservation and distribution of fish. In the United States quick-freezing of ready-to-cook dressed fish was, apparently, first commercially undertaken in 1924 by the author who was closely followed by Cooke and Kolbe. Most of the fish fillets and steaks quick-frozen on the Atlantic Seaboard of the United States during the last eight years have been prepared by these three systems. The Cooke and Kolbe apparatus have been used principally for freezing single pieces of fish before they are wrapped, whereas the Birdseye system was developed with the idea of packaging many kinds of perishables first and freezing them afterwards.

The growth of the quick-frozen fillet industry since the beginning of 1924 has been tremendous, 21,632,000 pounds of fillets having been quick-frozen in 1929 alone. Although the application of quick-freezing to the shellfish industry is comparatively new, it is particularly advantageous for both mollusks and crustaceans because ordinary "sharp" freezing damages these delicacies even more than it does other varieties of seafoods. Oysters, clams, scallops, lobsters, crabmeat, and shrimp are already being quick-frozen on an increasing scale. Much of the shrimp is exported to Japan, where it is a favorite and costly delicacy. Extensive experiments have definitely indicated that mussels, hard clams, spiny lobsters, soft-shelled crabs, abalones, periwinkles, and whelks may all be successfully quick-frozen when occasion arises.

Additional reasons why shellfish may be frozen advantageously are that they are seasonal and difficult to transport and distribute unfrozen. Oysters and soft clams are at their best in the early winter months. Scallops (of the "Bay" type) are of highest quality and most available in November and December. Lobsters are caught from early spring to late fall, but because they are used so extensive-

ly at seashore resorts are most available for quick-freezing just before and just after the summer season. Maine mussels seem to be at their best in April and May, before the spawning season starts. The Pacific Coast mussel is said to be actually poisonous at certain seasons of the year.*

The principals of some of the most important types of quick-freezing apparatus have already been touched upon, but it should be clearly understood that quick-freezing to attain its maximum value, needs to be accompanied by other factors, such as the backing of a strong, aggressive organization to promote the idea and to develop a system of getting perishable products from the producer to the consumer by means of low temperature. Products must be properly selected as to species and quality, correctly pre-treated and packaged before freezing, quickly frozen, suitably cold-stored, transported without being allowed to thaw, retailed efficiently while held at temperatures only slightly above zero, Fahrenheit, and properly cooked. Any commercial quick-freezing undertaking which fails to take into account all of these factors has little chance of success.

Since properly frozen shellfish tissue is practically imperishable, and since it is packaged with all waste eliminated at the production point, it may be economically sold throughout the year and in a vast territory where it is not now obtainable. Moreover, trade in these products will become increasingly international in scope. Already successful commercial shipments of oysters, clams, scallops, and lobster meat are being made from New England to Hawaii and the Panama Canal Zone. Experimentally, these products have been shipped from Boston to Buenos Aires and New Zealand. It is now entirely possible to serve perfectly fresh New England oysters, scallops, and other delicate shellfish in Yuma, Cairo, Manila, or anywhere else where modern refrigeration facilities are available.

Up to the present time quick-freezing has had no appreciable effect on shellfish production. Yet our natural uncultivated supplies of some of these delicacies are already overtaxed. During 1930 there were produced 15,000,000 pounds of lobsters worth $4,877,000; 89,500,000 pounds of crabs worth $2,597,000; 26,363,000 pounds of clams valued at $3,600,000; 92,327,000 pounds of shrimp valued at $3,134,000; 6,667,000 pounds of scallops worth $1,210,000; and 124,968,000 pounds of oysters valued at $16,306,000. Thus a total of 354,825,000 pounds of these shellfish, worth more than $30,500,000, were produced in one year in the United States alone.

Present and probable future consumption figures are illuminating. Although accurate figures are not available, it is probable that the annual per capita consumption of seafoods in the United States is about fifteen pounds. The amount eaten is, of course, greatest along

*"Mussel Poisoning on the Pacific Coast," by H. Sommer, Hooper Foundation, University of California (presented August 19, 1931, before Joint Session of National Shellfisheries Association and the Oyster Growers and Dealers Association of North America, Inc., at West Sayville, New York).

the seaboard and in large cities which have good rail connections with the fishing centers. New York City shows a consumption of thirty-two pounds of fresh and frozen fish and shellfish. Pittsburgh consumes eleven pounds, and Louisville, Kentucky, six pounds annually. Even in cities in the Central and Rocky Mountain States consumption of fresh (as opposed to canned seafoods) is very low indeed, and in rural districts of those sections practically no fresh seafoods are eaten.

There are in the neighborhood of 500,000 listed retail food outlets in the United States. Only about 6,000, or 1 1-5%, deal principally in seafoods. While it is true that perhaps from thirty to fifty thousand more food stores handle some form of fresh and frozen fish occasionally, most of these stores do not handle any fresh shellfish; and it is very doubtful if the total number of stores selling shellfish exceeds fifteen thousand. It is obvious, therefore, that when shellfish are included in a complete line of quick-frozen perishable foods, distributed throughout the year in every city, town, and village from coast to coast, the increase in consumption will be tremendous. There will be an almost unlimited demand for lobsters, crabs, clams, shrimps, scallops, and oysters. American waters can not possibly meet this demand without the intensive application of scientific handling and fish cultural methods. A great deal of this sort of work has already been done in the propagation of oysters, but there remains a very large field for the scientific production of lobsters, crabs, clams, scallops, and shrimp.

It is an undeniable, though to my mind regrettable, fact that up to the present time the membership of the American Fisheries Society has had little interest in the commercial fisheries. But I am confident that the coming need for intensive scientific fish cultural methods in the shell fisheries will form a bond of sympathy and cooperation between commercial interests and the fish culturists of the United States and Canada, and lead to ever closer cooperation between sportsmen, scientists, and commercial producers.

Discussion

DR. EMMELINE MOORE (New York): Have you distributing centers in the large cities inland?

MR. BIRDSEYE: No. At present we have 450 stores which handle the products, mostly in New England, where we started. They extend as far south as Washington, where there are two stores, and as far west as Pittsburgh and the central part of New York State. We are careful not to go into isolated regions because we want to have a central service station in each locality.

PRESIDENT RODD (Ottawa): Do you recommend any method of thawing before these products are prepared for the table?

MR. BIRDSEYE: Except with roast poultry, which has to be limber enough to be stuffed, we recommend that frozen foods be cooked without thawing,

so that when they have once been thawed the flesh is just the same as before freezing. These products are taken when fresh at the production point and they are handled with extreme sanitary care. The actual freezing operation destroys some 50% of the bacteral content but naturally it does not sterilize. When the foods are thawed they are freer from bacteria than the ordinary food product.

DR. TRUITT (Maryland): I should also like to ask if the very low temperature affects the vitamin content of the foods.

MR. BIRDSEYE: Generally speaking the vitamins are destroyed by oxygen and heat. In other words, the higher the temperature the faster they are destroyed. We have not found any instance so far in which the vitamin content of the frozen product is injured in any way. Experiments in that direction have not been nearly as extensive as they should be, and I cannot speak conclusively. I can say, however, that careful and extensive experiments with orange juice and milk which had been frozen for about seventeen months and shipped by means of dry ice from Gloucester to Battle Creek, Michigan, did not give any evidence of loss in vitamin content. There is nothing in our knowledge of vitamins that would indicate that the frozen products, properly packaged and properly stored, should lose their vitamin content.

MR. ROWE (Maine): A question of interest to the commercial hatchery men is the possibility of freezing brook trout for the market.

MR. BIRDSEYE: Brook trout freeze in excellent shape. I think there is a tremendous future for quick-frozen brook trout. I have never yet found, however, a commercially reared trout which had the color and the flavor of a wild trout. Several of the commercial breeders are endeavoring to work out methods of improving these factors, and some of them have succeeded in developing an excellent color. Mr. Rowe has shown me trout which were as brilliantly colored and the flesh of which was as pink as that of any wild trout. Even with the present disadvantages as to flavor and color, our frozen trout business is building up quite rapidly.

IMPROVED EQUIPMENT FOR LOBSTER REARING

EBEN W. COBB

Supt. Fish Restoration, Connecticut Board of Fisheries and Game

I am taking for my subject a matter which for many years has not received attention from this Society, namely lobster hatching. Several articles appear in the older reports showing the experimental work conducted by the Bureau of Fisheries and the State of Rhode Island, largely by the State of Rhode Island.

In years past hatching was carried on by the Bureau of Fisheries, but as the hatch was apparently much less when artificial means were employed than under natural conditions and a better scattering of the fry was secured under natural conditions the artificial hatching was given up.

In 1910 Francis H. Herrick in a paper read before the Society said "The hatching of the eggs followed by immediate liberation of the fry is ineffective." The correctness of this statement has not been questioned and I believe all have been agreed that the fourth stage is the necessary age to which lobsters should be reared if results were to be secured. There seems to be no disagreement as to the fact that eggs should be allowed to hatch and the fry taken at once to the rearing equipment. Some have at times been allowed to hatch in the receptacle in which they were to be reared, but this seems to have been less successful than using the rearing equipment solely for rearing purposes.

The difficulties in the way of artificial rearing were well stated by A. D. Mead, of Providence, R. I., in a paper submitted in 1905. He enumerated the difficulties as follows: "first, their terrible cannibalism; second, the difficulty of keeping them properly aerated and free from fouling from their decaying food; third, the supply of proper food; fourth, protection from a growth of diatoms and other vegetable and animal forms, which appear on the surface of their bodies and prevent them from swimming and feeding." To overcome these four difficulties has been the problem of lobster culturists since that time.

The work in Connecticut in this line was described in our biennial report for the period ending June 30th, 1930. The object of this paper is to bring it to the attention of this Society, and, if possible, to arouse some interest in the lobster question which is a serious one to the fishermen of the entire northern coast of the United States and Canada.

For many years work has been carried on by Rhode Island in the rearing of lobsters in containers floated on a raft, the water being

agitated in these containers by propellers turned by power. During a considerable part of this time Connecticut has made it a practice to secure egg-bearing lobsters from the fishermen, paying them for the same, tagging them and releasing them to allow for natural hatching. This was done for the purpose of preventing to some extent the illegal sale of egg-bearing lobsters and in no way increased the hatch beyond what it would have been had all such been returned to the water as the law required.

In 1929 Connecticut undertook to devise a system which could be worked out in our hatchery at Noank and with which a complete check could be maintained at all times upon actions of fry and their growth. We believe that with this system we can be much more sure of results and secure more valuable information than under the system of boxes or bags suspended on rafts.

The reason for selecting the fourth stage as the stage to which the fry should be reared is that the newly hatched lobster swims at or near the surface of the water and is easily taken by all fishes or other animal life looking for food. At the fourth stage they seek the bottom and look for hiding places. It is presumed that during the period of free swimming the greater part of the loss which reduces thousands to single individuals takes place though from then on and at all times some loss must be taking place.

Under our present system the egg-bearing lobster is confined in a trough where the fry hatch. The fry then pass to a section in the lower end from which they are removed to the rearing boxes. The boxes are 16 inches square and 14 inches deep. A current of water is discharged from the center so as to cause a continual circulation which keeps the fry in constant motion so as to prevent their grabbing one another.

The advantage of our system is that all can be clearly seen and in case the fry have a tendency to collect in any spot, the jets of water can be so turned that such tendency is broken up. This helps largely in overcoming any little unevenness in the flow. Also we can see if all food is eaten and remove any which is not.

The second difficulty, that of maintaining aeration, is overcome by the constant whirling motion with a fresh stream of water coming in at the bottom and an equal amount going out at the top. The boxes also can be scrubbed at any time as easily as the trough ordinarily used for rearing trout.

The prevention of growths on the fry is best taken care of by proper screening of the water and keeping all equipment clean.

With good feeding the stages are somewhat shortened on account of more rapid growth, and in this manner the dangers are proportionately lessened.

This season we have obtained fry from 455 egg-bearing lobsters

and from these we have produced and planted by actual count 151,258 lobsters of fourth stage or over. After reaching this stage there seems to be no great advantage in holding them except for observation. For that purpose we have successfully held some fry to the seventh stage.

We feed our fry once each two hours on finely ground beef liver. This is the cleanest food to use and we find it more satisfactory in every way than fish. It is a night and day job during the season which lasts during the months of June, July and August.

I shall not attempt to describe the apparatus in detail as it is much better shown by the accompanying diagram. The box is designed for the purpose of observation. It is sixteen inches square and fourteen inches deep and can be set on tables. At the centre is an outlet pipe. The overflow is protected by a screen. The inlet comes through a tube into a circular container, and from there the water is discharged through very fine holes directly at the bottom so that a fairly small stream of water runs through the tank with a constant boiling motion. The box is painted, with white enamel on the inside so that it is easy to keep clean. You can learn a good deal about lobster fry under these conditions. They are held in a building, under cover, the same as you would carry fry in a trout hatchery.

We have carried on this work for three seasons and reports are received from lobstermen that more small lobsters are seen than in times past. They attribute that fact to this work. It is perhaps possible that if other states and the Bureau of Fisheries would take an active part in the rearing of lobsters, the supply could be greatly increased.

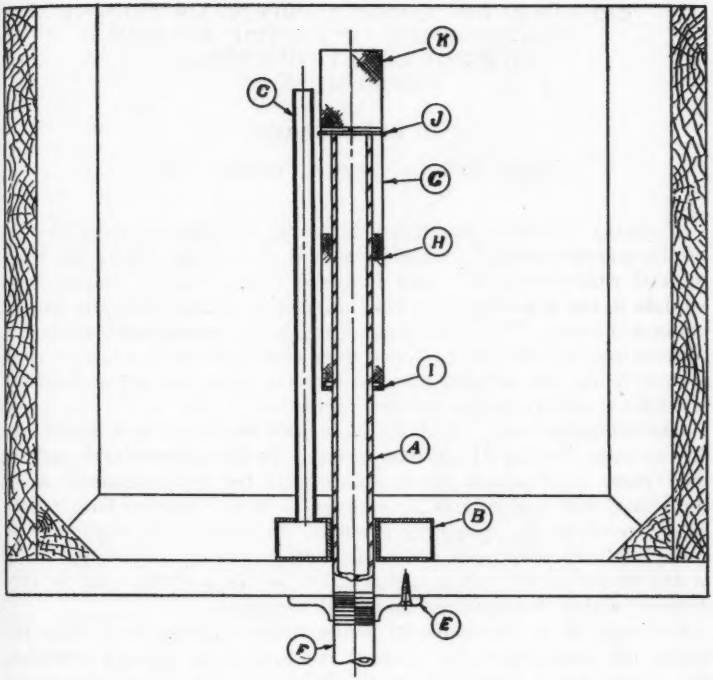
Discussion

MR. O'MALLEY (Washington, D. C.): In the old days when they started the lobster hatchery in Rhode Island, the Bureau looked into the matter and at that time it was thought that that type of hatchery for lobsters would not be successful on the Maine coast on account of the colder temperature. I wondered if that was a consideration that entered into the matter.

MR. COBB: The temperature of the water makes a difference in the period of growth, and of course the period of growth does have a bearing on the loss. The advantage of this plan is having the whole hatching in one building to which water can be piped from a convenient source. The use of a building is no more expensive than operating a raft in tide water.

MR. O'MALLEY: How many lobster fry do you carry to each compartment?

MR. COBB: You may carry an initial stock of five or six thousand. Of course the more you put in the more likely you are to have a heavier percentage of loss. The period of development is not so long as to prevent your using the same box several times during the season.



CROSS SECTION SIDE VIEW OF LOBSTER REARING BOX

See Text for Dimensions

LOBSTER REARING BOX

a. A three-quarter inch standpipe.
b. A loosely fitting brass circulator for distributing the water in the rearing box.
c. Copper supply pipe to water circulator, eleven inches long by one-half inch in diameter.
d. A three-quarter inch brass floor flange.
e. A three-quarter inch brass nipple to provide for draining the box.
f. A two-inch copper pipe three inches long furnishes the outlet screen.
g. Cylinder of No. 18 mesh wire cloth, 4 inches long.
h. Circular disc at bottom of screen, with a hole of suitable diameter to fit closely over the overflow.
i. Two cross wires at top of pipe which hold screen in position.
j. A cylinder of No. 14 mesh brass wire cloth, two inches long.

RELATION OF TAGGING PROGRAMS TO THE CONSERVATION OF PACIFIC SALMON OFF THE COAST OF BRITISH COLUMBIA

A. L. PRITCHARD

Pacific Biological Station, Nanaimo, B. C.

Probably the most important factor in the general consideration of the conservation of Pacific salmon is the regulation of the commercial catch in such a way that the escapement of mature individuals to the spawning beds will provide a seeding adequate to perpetuate the run. This balancing of catch and escapement might not present unusual difficulties if one were concerned with a simple river system where the salmon come in directly from the sea and fishing is confined wholly to the estuarial area.

Unfortunately recent findings have indicated that such conditions do not exist for any of the five species. In an extreme case such as the Fraser river where the migrants pass for long distances along the coast, and are subject to capture at many intermediate points before reaching the spawning grounds, the problem of regulation is exceedingly complex. In every instance, however, a thorough study of the routes of migration is demanded before a system can be formulated which is applicable under all conditions.

Obviously it is impossible to define routes of migration from the sea to the spawning areas without recourse to a detailed examination of the actual movements of the fish. The fish, themselves, must provide the data. Such information has been collected through the medium of tagging.

In 1925, at a meeting in Seattle, Washington, of the International Pacific Salmon Investigations Federation, composed of representatives from the United States and Canada, it was resolved that an extensive tagging program be carried out in the waters off the coasts of California, Oregon, Washington, British Columbia and Alaska. The Biological Board of Canada, with the cooperation of the Department of Fisheries, immediately began along the coast of British Columbia the Canadian portion of the general plan. Further work was completed during the years from 1926 to 1930 inclusive.

In British Columbia, the tag employed for adult salmon was an aluminum band about three-eighths of an inch broad, less than one-sixteenth of an inch thick, and two and three-quarters inches in length. For the smaller, immature fish, a monel metal strap about one-half this size was used. On the face of each appeared the serial number and the initial letters of the province. These tags were af-

fixed to the upper edge of the tail by the use of a special pair of pliers. Records were taken of the date, place and round weight of the fish at the time of tagging, and scales were removed for later studies on the age compositions of the various runs.

In view of the fact that spring and coho salmon are taken on the troll and the other three species are captured in purse seines two different methods of procedure were developed. In the former case, taggers went directly on board the fisherman's boat and tagged those salmon which were not injured when caught. In the latter case, it was necessary to employ an auxiliary vessel from which to tag the fish which were obtained from the purse seiners. In both types of experiments, however, the fish taken constituted a random sample of the commercial catch.

For the return of tags, the Biological Board of Canada set the nominal sum of fifty cents and appealed to the men of the fishing industry for their utmost cooperation. The data requested were the date and place of capture and the round weight. The results of this procedure have been very gratifying.

Since it is plainly impossible in a general discussion to present in detail the returns for all the programs, a brief resumé of the findings for each species is given

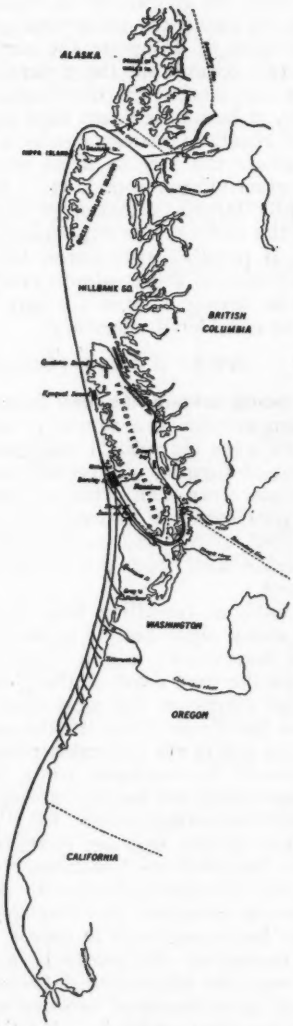


FIGURE 1
Showing the general geography of the Pacific coast, and the graphic illustration of tagging returns.

herein. Figure 1 has been inserted for the guidance of those unfamiliar with the geography of the coast, and to illustrate the method used in recording the recaptures graphically. The lines thereon are not intended to designate the exact route followed by the salmon, but merely to indicate the general direction suggested by the data.

After considering the distribution of recoveries from the various districts, it became evident that intensity of fishing had had a noticeable effect. Greatest numbers were usually recaptured in districts where the largest fleets were operating, e. g. Skeena river, Fraser river, Puget sound, etc. Returns from smaller rivers were apparently largely a matter of chance. This condition in no way lessens the value of the experiment since the original aim was to establish, if possible, the source, but more particularly the main migration routes of those salmon taken in the commercial catches, with a view to laying a basis for any measures of conservation which might be considered necessary.

Spring Salmon (*Oncorhynchus tschawytscha*)

The spring salmon has been found to make a long and complicated migration usually in a southerly and easterly direction. Only in a few cases were individuals recaptured in an area farther north than the point of tagging. Especially noteworthy is the recovery in the Sacramento river, California, of two individuals tagged at Ucluelet, on the west coast of Vancouver island, 820 miles distant. In 1930, almost 50% of the returns from the west coast of the Queen Charlotte islands were from the Columbia river which is over 650 miles southward.

This habit of travelling long distances exposes these fish to capture in many areas and thus increases the difficulties of any measures of restriction. As an illustration, spring salmon from Hippa island, on the west coast of the Queen Charlotte islands, were taken at several places on the west coast of Vancouver island, in Puget sound, in the Fraser river, off the coast of Washington, off the coast of Oregon and in the Columbia river. As a result, however, of these recaptures at intermediate points, an indication has been given of the routes which are usually chosen.

Several interesting points are illustrated by Table I which embodies for all the tagging districts the percentage of the returns from the Fraser river, Columbia river, all Canadian waters and the United States waters exclusive of Alaska.

At once it is evident that any thorough consideration of this species must be international in aspect. From every area investigated in British Columbia, the southerly and easterly migrations have extended over the international boundary. The numbers of fish, so travelling, have amounted in some cases to over 85% of the total.

It has also been established that the returns from the United States waters become fewer as the tagging base moves farther northward,

those from the west coast of Vancouver island averaging approximately 80%, from the west coast of the Queen Charlotte islands, 65%, and from the north coast of the latter and from Hecate strait, 51%. Such a condition not only complicates any attempt at regulation, but also indicates that if tagging were carried on for this species in Alaskan waters, it might be found that the runs there were constituted of fish bound mainly for Canadian waters.

TABLE I

Giving for spring salmon the percentage of returns from the Fraser river, Columbia river, all Canadian waters, and the United States waters, exclusive of Alaska, for all tagging districts.

Area of tagging	Year	Number tagged	Per cent return	Percentage of returns			
				Fraser river	Columbia river	Canadian waters	U. S. waters (exc. Alaska)
NORTH COAST:							
Queen Char. id.	1929	402	14.9	31.6	21.6	50.0	48.3
do	1930	660	15.0	16.2	27.3	40.4	58.6
Hecate st.	1930	182	7.2	7.7	30.8	46.1	46.2
WEST COAST:							
Queen Char. id.	1925	274	13.5	10.8	27.0	27.0	70.3
do	1929	375	10.9	17.1	14.6	43.9	56.1
do	1930	179	13.4	16.7	41.7	25.0	70.8
MILLBANK AND FITZHUGH sd.	1930	302	5.0	26.7	13.3	86.7	13.3
VANCOUVER id.:							
Hardy bay	1930	436	6.2	----	16.7	33.3	66.7
Kyuquot	1927	517	14.1	1.4	64.4	12.3	87.7
Ucluelet	1925	1,125	10.8	4.1	60.7	17.2	82.8
do	1926	1,353	13.1	6.2	60.0	17.5	82.5

Coho Salmon (*Oncorhynchus Kisutch*)

In view of the fact that the coho salmon spawns in practically all streams, whatever their size, it is unlikely that the necessity for the limitation of the catch will arise as quickly for this species as for the spring, which usually spawns only in the larger rivers. Should the need occur, however, tagging has demonstrated that the concern should lie chiefly with the local government since migration is much more restricted. On the other hand, in the case of extreme depletion international co-operation must be enlisted because as many as 24% from the north coast of the Queen Charlotte islands were recaptured in Alaska, and approximately 30% from Deep bay and Nanaimo were returned from areas off the coast of the United States.

Within territorial waters the findings have shown the situation for the coho to be usually somewhat complex in view of the fact that

migration seems haphazard although limited. Many individuals were found in areas north, south and east of the tagging base. In other cases, like that of the strait of Georgia, the same stock apparently remains in a more or less confined area throughout its whole life.

Pink Salmon (*Oncorhynchus Gorbuscha*) and Chum Salmon (*O. Keta*)

It is unfortunate that so little work has been completed on these species which are taken in purse seines, but which do not usually "take a spoon." The data which have been obtained have been confined to southern British Columbia and have demonstrated that both species may reach the southern rivers of the strait of Georgia and Puget sound by way of inside channels from the north end of Vancouver island. In addition, the pink resembles the spring, coho and sockeye, in that it also migrates around the south end of Vancouver island through the strait of Juan de Fuca.

Sockeye Salmon (*Oncorhynchus Nerka*)

The main interest in the case of the sockeye has centered around the Fraser river. In 1918 O'Malley and Rich tagging at Sooke on the southwest coast of Vancouver island showed that the routes most commonly used by this species "passes from the strait of Juan de Fuca across Washington sound to the Salmon Banks and Whidbey island, then through Rosario strait and the southern part of the Strait of Georgia, past Point Roberts to the mouths of the Fraser river." The result was that this run which spawned in a Canadian river was captured principally by United States fishermen. Later tagging demonstrated, however, that another migration of sizeable proportions took place to the Fraser from the northern end of Vancouver island through the strait of Georgia. A similar international aspect in respect to sockeye was indicated at Haystack island near the Alaskan boundary when 20% of the recoveries were made in Alaska.

All the programs mentioned thus far have had as their object the establishment of the general trend of migration in the sea. In 1928, the method was applied to a restricted sockeye problem on the Fraser river. The purpose was to attempt, by tagging a representative sample of sockeye, each day throughout the season, near the mouth of the river, to determine whether those bound for various tributary streams enter and pass up the river at different times, or whether the distribution is uniform throughout the period of the runs. Due to the fact that fishing is carried on for some distance up the river, it was necessary in order to lessen the chances of recapture in the commercial catches to take the fish above the limit before releasing them. It was found that any attempt to hasten the trans-

fer from salt water to fresh, a change which usually takes place in a leisurely manner, would likely be unsuccessful.

As a result of this experience, it is felt that the manner in which to obtain data on this very important question is to carry out a comprehensive tagging program in the areas which supply the river, e. g., Sooke, Puget sound, and the lower reaches of the Fraser, allowing the fish to migrate as usual through the fishing districts. The resulting data, together with that obtained from a close examination of the spawning streams, would lead, it is hoped, to the determination of a relation between the time of the run and the probable escapement, thus laying the foundation for the control of numbers passing to the various tributaries.

SUMMARY

Through the medium of tagging programs, it has been possible to demonstrate that in the waters off the coast of British Columbia, there is a widespread fishing drain on the run of Pacific salmon. At times the migrations of these fish are long and complex, reaching across the international boundaries, e. g., spring salmon. At other times they are shorter and more simple, usually confined to territorial waters, e. g., pinks, chums and cohoes. On occasion, however, even the latter may enter foreign territory.

At the present time, various regulations designed to ensure an adequate escapement are in force along the coast of British Columbia. If extreme depletion of any species should occur, it might be desirable to enact legislation restricting capture throughout its range. Tagging operations have forcibly indicated the need for international co-operation in this connection.

COMMENTS ON FISHERIES STATISTICS COLLECTED IN CALIFORNIA

W. L. SCOFIELD

California Division of Fish and Game

Conducting a business requires bookkeeping to give at least a fair idea of the kind, size and location of the enterprise, stock on hand and sales records to show volume handled of each type of goods for seasonal and annual periods. A farmer knows the extent of his land and the kind, volume, quality and value of the crops produced on each portion of the farm. Wiser farmers have accumulated records from past years to help in the estimate of the normal variation from the average yield per acre which may be expected under certain conditions.

Proper administration of natural resources requires such a bookkeeping system and, the greater the accumulation of adequate and comparable figures for past years, the more confidently may the various phases of administrative policy be determined and put into operation. The more effective the administration, the more exacting is the necessity for complete and detailed records to serve as a basis for all phases of the work.

In fisheries conservation the aim is to so manage the resource that it will continue to yield a high annual return without cutting down the growing stock sufficiently to seriously lessen future yields. This entails an estimate of the comparative extent of the growing stock from year to year, the maximum annual yield that may be harvested with safety and the determination of the first evidences of overutilization that may appear in the growing stock. Other administrative, economic or biological questions are secondary. Comprehensive knowledge of the growing stock, its extent, changes, and the degree of proper utilization can be gained only from the use of accumulated detailed records, so that it is not an exaggeration to say that the establishment of an adequate system of fisheries statistics is a primary consideration and serves as the foundation for proper administration of the resource. Without basic information, the policy followed is that of the opportunist who dallies with first one and then another secondary problem, resulting in the expenditure of time and money netting the administrator only a few unrelated scraps of information, which are next to useless in the wise management of the business.

Total catch figures picture the extent of the business activity in each fishery, but such totals give us little knowledge of the growing stock, or of the changes that may be taking place. This is because the volume of catch is not necessarily determined by abundance of

fish in the sea and certainly a progressive change in amount of catch does not indicate a corresponding increase or decrease in the supply. More frequently a greatly increased catch results in fewer fish remaining in the water and there have been frequent examples of a fishery suffering heavy over-utilization through a series of years when the total catch was steadily mounting because of steadily increasing fishing effort. During such a period of overharvesting, it is difficult to convince the men engaged in the trade that there will follow a period when still greater fishing effort will not yield a greater catch and that in extreme cases the total catch collapses in spite of all that fishermen can do to maintain it.

Obviously the amount of catch is influenced by other factors besides the available supply of fish. Fishing effort involves the kind and amount of fishing gear in use, its effectiveness and methods of operation. Adverse hydrographic conditions sometimes reduce the catch for long periods. A complex of economic factors may reduce or increase the total catch by profoundly influencing the fishing effort. It is necessary therefore that catch figures be recorded in terms of yield per unit of fishing effort if they are to tell us anything of the supply of fish and changes in the growing stock.

It is necessary also that records of fish landed be supplemented by data indicating the amount, kind and operating methods for all fishing gear, number of men and description of boats used, price fluctuations and other changing economic conditions, as well as biological observations, particularly as to the percentage of fish of each size class appearing in the catch. A change in the catch of fish per unit of fishing effort is frequently the result of man's fishing activity but hydrographic or other causes may result in a long-time cycle or change in abundance for which man's fishing is not responsible. It is for this reason that a biological study of sizes of fish landed is of such importance since the detection of a change in the normal proportion of size classes may distinguish between over-utilization and a natural cycle of abundance.

It should be of interest to sketch the establishment of a particular statistical system as an example and to comment on the problems solved and those still awaiting solution. In California an adequate system for fisheries statistics was carefully planned and put into execution. At once it was discovered that no system however complete will operate itself but needs constant supervision from someone with a broad understanding of the ultimate aims and uses to which various types of data can and should be put. It was discovered also that even a well planned system soon becomes partially inadequate because conditions in the fisheries are constant only in that they are constantly changing and the manner of collecting data must necessarily change to keep pace with altered requirements. But while changes are being made it is requisite that the real purpose of the statistics be kept in mind—the use of the data in judging the supply,

determining the proper degree of utilization of that supply and the discovery of the first indications of over-harvesting. There is always a tendency toward allowing a statistical system to degenerate into chamber of commerce totals of business transacted.

Within the California Division of Fish and Game, a Bureau of Commercial Fisheries was organized. Previously, an annual catch total for each species had been considered sufficient but the newly formed bureau wished monthly figures so that the seasonal runs of fishes might be determined and, as a result, in August, 1915, each fish dealer in the state was required to send in a monthly statement of the amount of each species purchased from fishermen. Soon after these monthly reports began coming in, it was recognized that these totals were of very limited use because they gave no indication of the fishing effort involved.

At the next meeting of the state legislature the law was amended (1917) to require that each dealer keep on file for inspection the record of the daily deliveries of each fishing boat. This attempt at arriving at catch per unit of effort was much too cumbersome and the following year (1918) a comprehensive plan for fisheries statistics was put into operation and enacted as law in 1919. It was recognized that dealers did not pay cash to fishermen but gave a receipt for each delivery. A duplicate was kept for the books of the firm. The receipt gave the necessary information for studies of catch in terms of fishing effort and from them the average daily boat catch, catch per fishing trip or average monthly catch for representative fishing boats could be computed for a series of years when records had been assembled and allowed to accumulate. It was realized that such records should be preserved since their value increased with age. To insure uniformity and completeness of these receipts the state printed and distributed, free of charge, receipt books, containing a carbon triplicate page to be torn out and deposited with the state for each delivery of each individual fishing boat in the state. The form included name of boat and captain, date and place of delivery, pounds of each species and price paid the fisherman.

The number of commercial fishermen was already a matter of record through the annual sale of fishing licenses but the previously collected data as to fishing gear were not in sufficient detail. Consequently it was required that each fishing boat should register annually and give a complete description of the kind and amount of gear operated and outline what gear was used in each fishery for each month of the previous fishing season. It was arranged also for cooperation between the staffs of the research and patrol departments in gathering supplementary information not included on the forms already mentioned. This provided for notes on the methods of operating fishing gear, changes and tendencies in the fisheries, and comments on such economic developments as would affect the success of fishing. In addition to this the research staff naturally col-

lected more detailed data for those fisheries which were the objects of special investigations.

As was to be expected, the first few years of the operation of this system offered a host of difficulties which, as yet, have not been completely eliminated. The carbon copy idea insured more comprehensive records at moderate cost than could be collected by field observers. As the record was the basis of a financial transaction between dealer and fisherman, accuracy as to amounts of fish was guaranteed in all but very exceptional cases where deliberate fraud could be practiced. In nearly every case we received the sincere cooperation of the men in the trade and this is an indispensable requisite for the success of any statistical system. Yet the catch records were made out by many and diverse fish dealers scattered from one end to the other of a long state. Omissions of desired information were too frequent at first and notations were often difficult of interpretation, especially when written in the Sicilian, Dalmation or Greek languages, but fortunately we were spared the deciphering of Chinese characters.

In order to be sure of the identity of the boat, three designations were required on the receipt form: 1. name of boat, 2. name of captain, and 3. Custom House number of the boat. Some of our fishermen had a huge relationship with even the initials duplicated in the name. Such girls as Daisy and Mary were entirely too popular, so that in many cases the name of a boat was no great help. Custom House numbers became hopelessly confused, especially at repainting of the boat when the fisherman reaching down from the deck tried to paint upside down such figures as 6 and 9. Most of this confusion was eliminated by the issuance to each boat of a permanent license number embossed on metal like an automobile license plate.

The coastal waters of California are really blessed with an unusual number of desirable species of fishes, but among our dealers and fishermen there is also a large number of different nationalities and these men from many parts of the world brought with them a weird collection of common names for fishes to add to the assortment of misapplied English names already in local use, so that we had six or eight names for one species while another favorite name did service for three or four species. In this confusion we regretted that the names "cod" and "bass" ever had been invented. We have finally cut down the superabundance of names and have greatly increased the certainty of species designation by issuing a booklet giving the officially adopted common name for each species with a photograph and description of the fish to which the name should be applied.

A minor difficulty has been to maintain uniformity in recorded weights so that figures may be strictly comparable from year to year. The basis for our weights is supposed to be the total pounds of fish in the round at the time of delivery. This disregards shrinkage occurring on the fishing boat. Whenever fish are gutted at sea an

adjustment should be made for cleaning loss, but this we prefer to do ourselves rather than invite confusion in the original record as made out by the dealer. Strict accuracy has not been reached, especially in those cases were a certain species is cleaned at sea for a part of the season or in certain localities and delivered in the round at other times.

When a fisheries statistical system was adopted in California there was little need to give special attention to recording the locality in which boats made their catches because fishing trips were short and catches were made locally for quick delivery to the nearest port. Since that time there has been a remarkable development in our fisheries and large boats equipped with insulated holds for ice or refrigeration plants now cruise along the whole coastline of the state, and tuna boats make trips to Central and South America. This means that point of delivery no longer serves as a catch locality record. In such cases we have had to gather supplementary locality records, although these additional data are by no means complete for all our fisheries. A plan has been tried on a very small scale by which the boat's log is inspected, but many of the captains keep logs so rudimentary that they are of little use to us. We are considering furnishing representative captains with log books printed by the state in hopes of encouraging the keeping of more complete locality records, but it is probable that we will have to continue and enlarge the catch locality notes kept by our field observers.

The question of fairly accurate catch locality records is a very pertinent consideration, as it is a basis for an important future improvement, or rather enlargement, of the California catch records now being discussed. Most catch statistics the world over are reported on the basis of land areas where the fish are delivered, probably because in origin the records intended to present the volume of business transacted at each port. There is no fault to find with this but, in addition, the fish yield of defined water areas should by all means be reported in these days when fish are transported long distances for delivery at several different ports. We hope therefore in future reports to show, at present, the volumes landed at each port from the different fishing areas and in addition to compile another set of reports to give the fish yield for certain water areas and indicate only incidentally were delivery was made. Obviously this is for the purpose of more clearly defining the production capacity and changes in yield from the separate fishing banks as an aid in their proper management.

The California catch figures are now being used for many administrative purposes and in studies of the degree of utilization of certain species. It is true that the records contain the material for all manner of special reports that are not now being compiled because of the clerical cost. Price studies showing the changes within a season, relationship to volume and to price of other species and the

trends from year to year would all aid us in understanding changes in fishing effort. Such reports have been rendered only when there was special need. We could have a complete report of the number of boats engaged in each fishery at all times, the transfer of boats from one fishery to another because of volume or price inducements and the migration of boats from one region of the state to another with the seasons or from year to year. We have a few such reports but the cost of compiling complete tables for every fishery has been prohibitive in the past.

An increasing need for such special reports has let us to adopt the punched card system for handling our catch records. Information from the original receipt record of a boat delivery is coded and punched out on a card so that sorting and tabulating may be done mechanically. The speed with which records can be rearranged and reported in whatever form desired is so great that the clerical cost of special reports is now comparatively negligible. The way is now open for our more complete appreciation of the worth of the statistical data we have been accumulating for the first fifteen years.

EXPERIMENTS ON THE MESH OF TRAPNETS AND LEGISLATION OF THE COMMERCIAL FISHERIES OF LAKE ERIE

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At the Minneapolis meeting of this Society in 1929 I discussed in some detail the more important problems that confronted the commercial fishermen of the Great lakes and presented the few pertinent data that were available to me at that time. Great progress has been made since 1929 towards the solution of many of these problems, and in the meantime new problems have arisen such as those involved in the introduction of the deep trapnet, a new type of commercial fishing gear to be reported on here by Mr. Fred Westerman, and in the tremendous spread of the smelt throughout the Great lakes.

At the Toronto meeting in 1930 I presented my solution of one of the principal problems of inquiry, namely, the sudden disappearance of the Lake Erie cisco in 1925. In fact, it was this particular problem that started the extensive limnological and fishery surveys of Lake Erie and initiated the development of an extensive Great lakes program by the Bureau of Fisheries. Every interested person wanted to know what happened to the tremendously valuable cisco fishery of this lake and what measures were necessary to bring the species back to commercial abundance.

I have already reported to you that the Lake Erie cisco was commercially exterminated by the bullnet, a deep gillnet some 100 meshes or approximately twenty-four feet deep, designed originally for the cisco. I do not intend to take up again this phase of the cisco question but wish to report briefly on the measures recommended for adoption in the rehabilitation of the cisco. I believe that the status of the Lake Erie cisco today justifies the absolute prohibition of the taking of a single individual. The Lake Erie cisco is at present as much in need of complete protection at all seasons of the year as is the lake sturgeon. Such protection could, however, not be given without stopping all fishing with gillnets, especially that in the eastern area of the lake. Such drastic legislation would not be warranted and needless to say would have no chance of enactment.

Two measures were finally proposed for uniform adoption on Lake Erie. First, the abolition of the bullnet. Secondly, the establishment of a closed season each year from December 1 to March 14, both dates inclusive. Both of these measures would give partial protection not only to the cisco but to other species of fish as well. At the

beginning of our survey in 1927 Ontario had already made provision in her statutes for the abolition of the bullnet on Lake Erie, this law to become effective as soon as similar action was taken by all the states on this lake. At the same time Michigan had restricted its gillnets to eleven feet as the maximum depth, although almost no gillnets are operated in the Michigan waters of Lake Erie. Pennsylvania had for some years made the abolition of bullnets a condition in the commercial fishing license, but since bullnets were permitted everywhere on the lake except in Michigan this stipulation was never enforced except for a short period in 1931. New York and Ohio had no restrictions on the depth of gillnets, although attempts to abolish them had been made in Ohio just previous to our investigation in 1927.

In 1929 a great advance was made when we succeeded in outlawing this net in Ohio. Attempts at that time for similar action in New York failed. But at a general conference of representatives from all the Lake Erie states and the province called by Commissioner Henry Morgenthau of New York at Buffalo, October 12, 1931, the question of the bullnet was thoroughly discussed and there New York together with all the other commonwealths agreed to outlaw this gear. Both New York and Pennsylvania have now completed the necessary steps and I am very pleased to report that the bullnet will be prohibited on Lake Erie after January 1, 1933, some six years after our investigations on the subject began. The various states and the province of Ontario are to be commended highly for their splendid cooperation on this question. Especially difficult was the situation in New York, where the department encountered vigorous opposition to the abolition of the bullnet.

The second measure, which provides a closed season on Lake Erie from December 1 to March 14, inclusive, is still under consideration. The first date, December 1, has been accepted by all the states and the province of Ontario while the second date, March 14, has been agreed upon by all except the province of Ontario. To give the cisco complete protection during the spawning period would require a closing date some time in November, but since we feel certain that an earlier date cannot be uniformly enacted at this time, we must accept the old adage that a half a pie is better than none. Perhaps sometime in the future we may be able to obtain the other half!

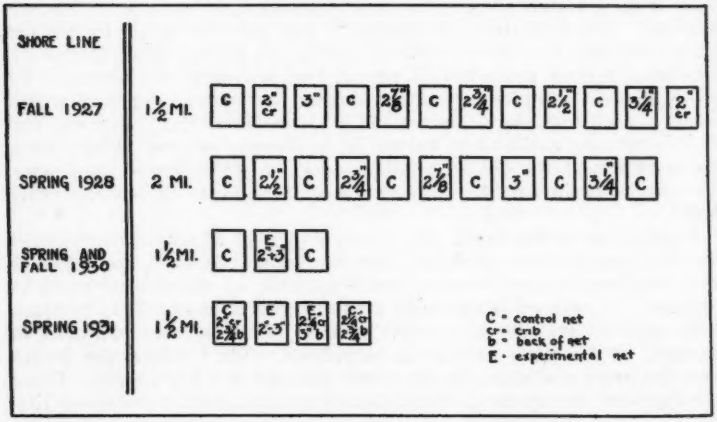
I come now to the main part of my paper, in which I wish to take up the second major problem that confronted us on Lake Erie. I refer to the extremely controversial question of the size of mesh in trapnets. A trapnet is virtually a submerged poundnet held in place with anchors instead of wooden stakes. The fish are captured in trapnets in the same way as in poundnets. They follow the leader into the heart and enter the first crib through the big tunnel. From this first crib they pass through a small tunnel into the second or lift-

ing crib from which they are removed by the fishermen. The mesh problem was attacked by fishing a series of experimental and control nets. The experimental nets were identical with the controls in every respect except in the size of the mesh in the lifting crib. It was hoped that by increasing the size of the mesh in this crib the principal objectionable feature of the trapnet, namely, the destruction of illegal fish, could be largely eliminated.

These experiments were conducted throughout various seasons of the year from 1927 to 1931, inclusive, and were modified from time to time as new information developed or as additional demands were made upon us by the fishermen. We have made every attempt to settle definitely this mesh question once and for all time. It is impossible to present in the time at my disposal here all our experimental data accumulated during the five years. Hence I have selected only certain data from each experiment which I believe will be sufficient to give you some conception of the nature and the results of this work. The complete data will be published later by the Bureau.

From September 26 to November 21, 1927, and from April 23 to June 20, 1928, we operated five experimental and six control trapnets, that is, a string of eleven trapnets, out of Sandusky, Ohio. Each experimental trapnet was placed between two controls and the data of each experimental net were compared with those of the two controls. The arrangement of the nets is shown in the accompanying diagram. The control nets were the regulation commercial nets

DIAGRAM SHOWING POSITION OF EXPERIMENTAL TRAP NETS IN LAKE ERIE
1927 - 1931



with two and one-quarter inch mesh in all parts of the lifting crib except the middle third of the back, which had a two and seven-eighths inch mesh as required by law. All parts of the lifting cribs of the five experimental trapnets also had a two and one-quarter inch mesh except that the entire backs of the various nets had different meshes of the following sizes respectively: 2½", 2¾", 2⅞", 3", and 3¼". In addition to these experimental nets we also operated with our series of 1927 two regulation commercial trapnets with 2 inch meshes in the lifting crib and with two and seven-eighths inch meshes in the middle one-third of the back. This was done because many fishermen employed a two inch mesh crib rather than a two and one-quarter inch. The second crib of all these nets had a two and one-half inch mesh throughout. Throughout the paper, measurements of mesh refer to stretched measure as manufactured.

In other words, in the fall of 1927 and in the spring of 1928 our experiments involved primarily a change in the size of the mesh in the back of the lifting crib of the regulation commercial trapnet to determine what effect such a change would have on the catch of illegal and legal fish and to determine how this effect would vary with the different sizes of mesh.

Data are shown in the table for two experimental trapnets of the series of 1927-28, namely, for the two inch mesh crib and the crib with three inch mesh in the back. The first column of figures in the table shows the percentage by number of illegal fish taken by the commercial trapnets in Ohio in 1927 and 1928. The mesh in the cribs of most of these nets measured two inches as manufactured. Some of these figures may astound you. The percentages varied from 29% in the case of the sauger to 92% in that of the perch. The second column of figures is intended primarily to show the percentage by number of illegal fish released when the two inch mesh lifting crib is replaced by a two and one-quarter inch. The figures show that in the fall of 1927 this increase of one-quarter inch in the mesh of the crib permitted the escape of 38% illegal perch, 90% illegal blue pike, and 64% illegal yellow pike at the sacrifice of a 36% loss in the number of legal blue pike. This 36% loss represented a loss of approximately 27% by weight. This loss was of course partly compensated by the 12% increase in the number of legal perch taken in the two and one-quarter inch net. The escaped legal blue pike unquestionably were the smallest individuals of that group, as is indicated by the fact that the average weight of the legal blues in the two and one-quarter inch net (7.1 oz.) exceeded that of those fish in the two inch net (6.3 oz.). This escape of the small legal blue pike is probably desirable since on the basis of sexual maturity the eleven inch size limit now in Ohio's statutes is too low. It should be twelve inches. Although it is not evident from this table, the percentages for the other three species of fish (sauger, striped bass, sheepshead) are based on too few specimens to be reliable. This

explains, for example, the inconsistency in the data for sheepshead, which show a release of 17% for the legal fish. It is of course impossible for legal sheepshead to escape through a two and one-quarter inch mesh. In fact, both the legal and the illegal fish in the case of the striped bass and sheepshead were of such size in 1927 as to make impossible their escape through a two and one-quarter inch mesh. The illegal fish of both species averaged about six and one-half inches in standard length. On the basis of this experiment no difficulties were encountered when in 1929 a law was enacted in Ohio increasing from two inches to two and one-quarter inches the size mesh permitted in the lifting cribs of trapnets.

The fourth column of figures in the table shows the percentage of illegal fish released by the experimental trapnet with a three inch mesh back. Figures are not shown for the other experimental nets of the series of 1927-28. The three inch experimental trapnet is reported on here since it was selected for further experimentation. From a comparative study of the data of all of our experimental trapnets the three inch mesh appeared to be the most desirable for commercial fishing in spite of the alarming percentages of release shown for the legal fish.

As I have already intimated, in spite of the extensiveness of our experiments, none of the percentages of release can be accepted unreservedly at their face value. They must be treated with a good deal of caution, and careful judgment is necessary to evaluate them correctly or approximately so. The values for each net must be carefully compared with those of the other nets in the series to study their consistency; account must be taken of the numbers of fish employed; the distribution and shoreward movement of the fish must be considered, as well as their average size. It would, for example, be foolhardy to contend that 28% of the legal sheepshead escaped through the three inch mesh when we know that it is physically impossible for any legal sheepshead to pass through this mesh. Each percentage then, unless consistent and reasonable, needs a qualifying statement. As stated before, time does not permit the presentation here of all the data used as a basis for my qualifying statements. These will be published elsewhere.

You will note from the table that the three inch mesh back released some 66% illegal perch and some 60% legal perch. Both values are too high—that for illegal fish only slightly so but that for the legal perch very much so. The former compares rather favorably with the comparable percentages of the other nets (not shown in table) but the latter does not. It is unreasonable to believe that 60% of the legal perch escaped through the three inch mesh when no legal perch escaped through the meshes of any other experimental net of the same series, which included a three and one-quarter inch mesh net. This three and one-quarter inch mesh net released some 55% of the illegal perch and this percentage compares favorably

with the 66% shown in the table for the three inch mesh back. We concluded therefore that the three inch mesh released a large percentage of the illegal perch without releasing many legal. This conclusion was later substantiated by the data of other experiments.

The values for the blue pike (80% and 51%) and for the yellow pike (71% and 42%) I consider at present only slightly too high for this net. Not enough specimens were available to give reliable percentages for the other species in these columns, although the percentage for the illegal striped bass (16%) I consider approximately correct. Both values for the sheepshead (56% and 28%) are radically inconsistent with other comparable data in spite of the fairly large numbers of specimens employed. On the basis of these experiments the size of mesh in the back of trapnets was increased in Ohio in 1929 from practically a two inch mesh to, not the size we wished, but to the compromise size of two and three-quarter inches—an increase of virtually three-quarters of an inch. This was at least one step forward.

Our next experiment was conducted at Lorain, Ohio, from November 11 to December 8, 1930. Here we operated one experimental trapnet with, not only the back, but with the entire lifting crib of three inch mesh. A regulation commercial net was used as a control. The data for this net are not shown in the table since this net was fished only a short time and was then modified for the experimental fishing of the following spring in 1931. Suffice it to say that the percentages of illegal fish released by this net exceeded those for the net with a three inch mesh in the back only. In spite of the small numbers of specimens employed, one very undesirable feature was brought out in the fishing of this net which induced us to modify it—a large percentage of the fish gilled in the large mesh during lifting. This led to the development of what we called a "hybrid" net in which we employed a three inch mesh for that half of the lifting crib opposite the tunnel end, including the entire back, and a two inch mesh for the other half or the tunnel end of this crib, including the tunnel itself. We believed that such a trapnet would permit many small fish to escape through the three inch mesh while at the same time the two inch mesh would prevent an undue amount of gilling during lifting. It is no doubt true that this small mesh will prevent the escape of some illegal fish that happen to be in the net at the time of lifting. But I do not believe that the difference between the number retained by the two inch and three inch mesh will compensate for the certain gilling of both legal and illegal fish that would take place in the three inch twine. It has been observed by us that during lifting the small fish crowd towards the top of the net, as they are usually found above the larger fish, and that it is not until the fish are crowded that the smaller individuals attempt to escape. But, if there are any numbers of legal fish in the

net at all, these first fill the meshes and thus hinder the escape of the smaller fish. At any rate, the illegal fish have only a slight chance to escape during the lifting of the net. And because of excessive gilling a three inch mesh would be much less desirable than a two inch. It is probably a question of selecting what we believe to be the lesser of two evils.

Our so-called "hybrid" trapnet was given a thorough trial and was fished at Lorain, Ohio, from May 1 to November 21, 1930, and at Sandusky, Ohio, from March 22 to May 18, 1931. The controls employed had a two and three-quarter inch mesh in the entire back of the lifting crib. The data for this "hybrid" net are shown in the last four columns of the table for the four most important species of fish. The percentages of release are as follows: illegal perch 61%, illegal blue pike 74%, illegal yellow pike 54%, illegal saugers 59%. This escape of the illegal fish was accomplished according to these figures at the loss of 9% by number of the legal blue pike and 35% by number of the legal saugers. This represents a loss by weight of about 4% in the case of the blue pike and 26% in the sauger. The catch of legal perch and legal yellow pike was actually greater in the experimental net than in the controls. On the basis of certain considerations which I cannot take time to discuss here I believe that the percentages for the saugers are too high, especially that of the legal fish. The percentages for the other species may be accepted as approximately correct.

But even though we accept all the values as they stand they should, in my estimation, convince any unbiased person that the "hybrid" trapnet is far superior to the regulation trapnet now in use and can be fished without financial embarrassment to the fishermen even during the first year of operation. Sorting out from 54% to 74% by number of the illegal fish at the relatively insignificant maximum loss of some 26% by weight of the saugers, which are usually taken in abundance only during a short period in the spring of the year, this trapnet should be eagerly adopted by the commercial fishermen of Lake Erie. It will save them a tremendous amount of labor in sorting the fish at the nets; it will save thousands of dollars in reducing wear and tear on their gear; it will save millions of young fish each year for future capture; and it may restore harmony between the two classes of commercial fishermen by partially removing one of the most objectionable features of trapnet fishing—the annual destruction of millions of young fish.

To bring home the conservational feature of a three inch mesh trapnet I may refer you to a paper prepared by Mr. Elmer Higgins and published in the Fishing Gazette in which he estimated, on the basis of the data presented by me at the A. A. A. S. meeting at Cleveland, Ohio, in 1930, that if a three inch mesh trapnet had been employed in Ohio in 1928 the number of fish released would have represented the survivors of some six billion fry. And "if this num-

ber were to be produced by hatcheries on Lake Erie alone it would require enough hatcheries to produce twelve times the present yield." Here is food for thought.

But, strange to say, in spite of all its excellent features, the adoption of this trapnet by the fishermen can only be accomplished by law. The recommended trapnet apparently must be forced on them although it is very encouraging to know that the company who operated our nets for us at Lorain, Ohio, has voluntarily adopted the "hybrid" net and has found it highly satisfactory.

And why should the fishermen in general exhibit such an attitude of opposition in spite of their excellent cooperation with us at all times? We have collected the necessary data to prove the fallacy of every one of their objections to the "hybrid" net. We can show that this trapnet will release illegal fish at the sacrifice of relatively few legal fish, that the escaped legal fish will not be taken by gillnets and other type of gear, that gilling of fish in the three inch meshes is slight, that such gilled fish are mostly of legal size and salable, and that our experiments were not hastily conducted but covered all fishing seasons throughout the year over a period of five years and two important fishing districts with somewhat different fishing conditions. Then why the opposition of the fishermen?

I believe it may partly be accounted for by some of their past experiences with the attempted passage of certain unsound or ruinous legislation proposed by unqualified or prejudiced people or based on inadequate field data. In our survey we have attempted to get at the unbiased facts. Never in the history of Great lakes investigations have so much time and money been devoted to a study of fishing gear as has been done in our investigation.

Five years of experimentation on one lake! This is wholly incompatible with the past experience of any fisherman on the Great lakes. He has been accustomed to investigations of fishing gear that often covered no more than one or two trips, if any, to his nets and to legislation drawn up on such inadequate data or based on the personal views of some commercial fisherman with political influence. This experience has been ingrained in him, is part and parcel of him, and it probably is too much to expect him to change over night. A non-political, unbiased, scientific investigation of fishing gear! That is incomprehensible to him! It is impossible! Five years of experimentation with one type of fishing gear! Say, the millennium must have come! It must be . . . . a dream!

A SUMMARY OF THE LIFE HISTORY OF THE COMMON SHRIMP (*PENAEUS SETIFERUS*) OF THE SOUTH ATLANTIC AND GULF COASTS OF THE UNITED STATES*

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The shrimp fishery since 1880 has been marked by a phenomenal increase in catch, doubling itself every eight or nine years, until in 1928 over 118 million pounds were taken in the United States. Since 1928, as a result of the economic conditions, the catch has fallen off somewhat. Of all the fisheries of the United States including Alaska, the shrimp in 1929 with a take of 113,263,000 pounds ranked ninth in volume and fifth in value. The value to the fishermen was $4,575,000.00. In this year (1929), 95% of the catch was produced by the states of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana and Texas. Louisiana alone yielded 43%, consequently making her by far the largest shrimp yielding state in the Union.

This important fishery of the South Atlantic and Gulf States is dependent upon three species of shrimp, *Penaeus setiferus, Penaeus brasiliensis* and *Xiphopenaeus kroyeri,* of the family *Penaeidae.* The Common shrimp (*Penaeus setiferus*) is the basis for about 95% of the fishery, while the grooved shrimp (*Penaeus brasiliensis*) and the sea bob (*Xiphopenaeus kroyeri*) together yield about 5%. In 1929, the take of *Penaeus setiferus* comprised about 100,000,000 pounds.

The data upon which this summary of the life history is based are too voluminous to reproduce here, since they consist almost wholly of total length measurements with observations on the state of development of the gonads of over 100,000 individual shrimp. Most of the conclusions here presented are based upon the Georgia data, since these data extend over the greatest period of time (October, 1930, to August, 1932) and are less fragmentary. Although, with

*The Shrimp Investigations inaugurated by the Bureau of Fisheries in 1931 are being conducted with the co-operation of the Louisiana Department of Conservation, the Georgia Department of Game and Fish, and the Texas Game, Fish and Oyster Commission. Field stations and laboratories are located at Beauford, North Carolina; Brunswick, Georgia; New Orleans, Louisiana, and Aransas Pass, Texas.

but few variations, the same explanations will hold for Louisiana and Texas.

From the interpretation of the data it is evident that spawning begins in March or April, depending upon seasonal conditions, and continues until August or September. Judging from the localities in which ripe individuals are found and from the localities in which spermatophore-bearing females are taken, it is most probable that spawning occurs in the open ocean or Gulf where the salinity is high.

The extensive plankton collections of the investigations have not, as yet, been studied in detail. As a result we are unable at this date to state anything definite concerning the larval stages. However, as shown by Müller, Brooks and Kishinouye the larvae of the *Penaeidae* hatch as nauplii and pass through several stages (7 to 9) including the zoea and mysis.

Nevertheless, the young post-larval stages ranging from 7 to 40 mm. have been seined in great abundance in the four states in which the investigations are in progress. These young are found on the inside in warm, shallow, brackish waters having mud bottoms. The young have been obtained in Louisiana as far inland as forty miles from the coast in waters with a salinity of only two or three parts per thousand. Apparently they move to the inside waters after having passed the larval period in the more saline waters of the open sea or gulf. They are first evident in April and May—grow rapidly and appear in the commercial catch in July at an average size of about 93 mm. By August they have increased to an average size of about 125 mm. During this period of rapid growth the young shrimp double their weight in nearly three weeks.

At the onset of cold weather in the fall, the growth apparently ceases or, at least, increases only slightly and the shrimp winter-over at an average size of about 135 mm. But with the coming of the warmer weather in the spring, there occur sudden changes in the shrimp population. The gonads mature rapidly, with spawning taking place within three weeks after the first appearance of the developing ovaries. A rapid sexual dimorphism takes place with the females soon outstripped the males in size until by June the females average 156 mm. while the males average only 144 mm., a difference of 8%.

At this time there is also an interesting change in the size-range of the shrimp. During the spring in each sex a distribution of wide range without a sharp mode is converted into a compact group with little variation of size and a well marked mode. This may be due to either the more rapid growth of the smaller and younger members or the disappearance of the larger spent individuals, or a combination of both.

That climatic and hydrographic conditions are large factors in the movements of the shrimp is evidenced by the fact that in Barataria bay, Louisiana, in the late summer and fall of 1931 there was a

high negative correlation ($r=-.7675\pm.07007$) between the changes in the average weekly air temperature and the changes in the average weekly per cent of females. In other words, when the air temperature was lower in one week than in the preceding week there occurred a greater proportion of females in the commercial catch. Likewise, an increase in temperature was associated with a decrease in the per cent of females. The males, necessarily, followed inversely.

During this same period there was also a high positive correlation ($r=+.5151$) between the average weekly temperatures and weekly average length of the females—the females in the commercial catch were larger on warmer weeks.

These findings are based upon the individual measurements of over 35,000 shrimp covering a period of fourteen weeks (August 17th to November 20th). The number of shrimp measured for any week never fell below 1,000 and many were over 3,000.

As the shrimp spawn they apparently die, at least no spent shrimp have ever been taken. Among the 18,487 female shrimp measured during the spawning seasons of 1931 and 1932, there were none that were in a spent condition. Another striking bit of evidence that points toward the death of the shrimp after spawning is the fact that after the appearance of the young shrimp-of-the-year in the commercial catch during July, which is near the end of the spawning season, the large mature shrimp rapidly disappear and after October no trace of them can again be found.

This being the case, the Common Shrimp differs decidedly from any other aquatic animal supporting a major fishery in that it has a life cycle of only one year. The entire catch (100,000,000 pounds in 1929) is composed of individuals that have not had and never will have an opportunity to spawn. As a result, if depletion ever sets in it is likely to run a rapid and disastrously precipitous course. Luckily, at present, no serious depletion is evident. We have found that the catch statistics kept by the various South Atlantic and Gulf states are quite inadequate for any analysis of abundance of the shrimp. However, steps are now being taken by Louisiana and Texas to provide adequate statistics, based upon the California system, so that when depletion occurs it can be detected, and protective legislation, based upon the fundamental biology of the shrimp, can be enacted.

PRACTICAL IMPORTANCE OF SECURING MORE PRECISE STATISTICS OF THE SHRIMP FISHERY

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Although the subject of this brief paper concerns the shrimp fishery, it is obviously applicable to commercial fishery problems in general. The shrimp fishery is a vast one, with an annual production of 113,000,000 pounds and a value of over $4,500,000 annually. It ranks eighth in volume and fifth in value of all the fisheries of the United States.

The Department of Conservation of the State of Louisiana, in conjunction with the Bureau of Fisheries of the federal government, is conducting an extensive and long-period investigation of the commercially important marine shrimp. To this program the States of Texas and Georgia, in lesser measure, are also contributing. The headquarters for this joint program are located in the laboratories of the Louisiana Research Bureau at New Orleans.

At the initiation of these researches it was apparent that the statistics of past shrimp production were valueless as data from which to determine the state of the fishery. It is the common experience of the fishery investigator that however adequate ordinary statistics may be for administrative purposes they are almost useless as biological data. To provide more precise statistics which would furnish adequate material for scientific analysis, the State of Louisiana is inaugurating a system of returns which will be briefly described. However, it is perhaps desirable to note first some of the factors which so completely impair ordinary statistics.

The primary object of every scientific investigation of commercial fisheries is to provide guidance in maintaining the fishery at its maximum production consistent with future welfare. It is clear that it is essential to learn whether the animals upon which the fishery depends are maintaining a constant level or whether they are increasing or are declining in numbers. These facts determine the whole procedure of exploitation or of protective legislative restriction.

Statistics gathered for administrative purposes are almost valueless, because they are reported as aggregates which are not capable of analysis into properly comparable unit values. The first need in estimating the welfare of any commercial fishery is to secure some index of relative abundance capable of application to the fishery concerned at different periods of time and in different localities. It is not only sufficient to know how many fishes were taken, but it is also necessary to know what effort was required to take them. In

other words, the reports of fishery production must be in such a form that we can evaluate the "catch per unit of effort."

For example, in the commercial shrimp fishery there are three species involved, *Penaeus setiferus, Penaeus brasiliensis* and *Xiphopenaeus kroyeri.* Of these the most important is *P. setiferus,* which constitutes a great part of the entire fishery and is the most important species of Louisiana, where over 43% of the total United States production is taken. Examination of the statistics of the fishery as a whole since 1880 has shown that production has doubled approximately every eight and one-half years, until in 1928 over 118,000,000 pounds were produced. As has also been shown, however, these figures provide absolutely no information as to the condition of the supply of shrimp.

During this period the shrimp fishing methods have undergone an evolution, changing from cast nets to seines and in more recent years to otter trawls. The cast net of fifty years ago is a net about eight feet in diameter provided with rings around the outside, a sort of draw cord, and a ring in the center. It is weighted on the outside. The fisherman using it holds one part of the net in his teeth. It is rather dangerous for the tyro to try it, because he is liable to lose a few of his incisors. The cast is made by spinning the net around in the air, then the draw cord is pulled, closing the bottom, and the net is drawn in. The shrimp was so abundant a few years ago that this extremely primitive device was sufficient. In 1916 the first shrimp trawl was introduced. From one trawl boat in 1916 the number rose to four in 1917 and 1,200 to 1,500 in 1932. It is perfectly evident that the effect of these different fishing methods differs so greatly as to render valueless any comparison of results secured by different methods unless correction for these differences in fishing practice be made.

Further, it should be observed that, however complicated the problem of the study of an animal may seem to the ecologist, the study of a marine commercial fishery is still more complicated. On the one hand we are dealing with the organism in its complex relations in the sea, its changing numbers, its life history, its food supply, its reproductive success, its enemies, both parasitic and predacious. On the other hand we are dealing with equally complex relations ashore, where the fluctuations of the commerce set a changing price upon the capture of the organisms and correspondingly cause an increase or decrease in the fishing effort. As Harden Taylor pointed out, this often serves to protect from extinction a commercially important species, but is of no use whatever in preventing depletion. In the case of organisms which give a high financial return, the incentive for the fishery may stimulate and maintain fishing intensity at a pitch that will send the species over the borderline into a state of dangerous depletion, which may result in catastrophe for the species. This economic factor thus modifies to an extreme degree the conduct

of the fishery and may cause extreme fluctuations in production, which are not at all a function of the numbers of organisms present. Thus, there have been in the shrimp fishery years of great abundance and low production simply because of economic dictates.

A second possible source of statistical material is to be considered, namely, the record books of private companies engaged in the fishery. Some companies in the Gulf States have been uniformly generous in making available for study all of their records. However, examination has shown that they are not the material desired, since the lack of uniformity makes impossible comparison of the records of one company with those of another, and even a comparison of the records of the same company at different periods of time, and also since long-period records of private companies are most rare, the longest available falling far under the requirements for a comprehensive study of long-period fluctuations, cycles in abundance or decline.

The State of Louisiana is placing in effect a system of shrimp returns which it is hoped will give statistics adequate for analysis in terms of production per unit of effort. Based partly upon the excellent system in force in California under the Californian statutes, 1919, chapter 550, and 1921, chapter 774, the Louisiana law will require triplicate shrimp receipts bearing the date, the name of the dealer, the name of the fisherman from whom the shrimp were purchased, the name of the boat, the number of the boat, the approximate locations at which the boat fished, the fishing method used (seine or trawl) and the length of the seine or trawl gear, and the pounds, baskets or barrels purchased, together with the price paid. These records will be collected by the agents of the Department of Conservation and penalties for failure to observe this law will be provided for adequate enforcement. The forms serially numbered and printed in books of 150 will be provided by the Department of Conservation and the procedure will be such that every book will be accounted for. It is believed that not only will this system fulfil the research requirements by providing the data we need, but it will also increase state revenues by a more accurate reporting of this taxable commercial production.

PROGRESS IN FISH CULTURE

C. F. CULLER

U. S. Bureau of Fisheries, LaCrosse, Wisconsin

After about thirty-two years of experience and contact with men of various qualifications in fish cultural work, the speaker believes Webster's definition of fish culturist, "a person expert or engaged in the propagation of fishes," is quite appropriate. How many of us are experts, and how many of us are just engaged in the propagation of fishes? The writer considers fish culture still in its infancy. The progress made in years gone by seems quite small when the length of time fish culture has been practiced is considered.

Previous to the past fifteen years, the fish culturist did not have to battle extremely adverse changes brought about by man in open waters. His task was not exacting nor conditions so difficult. Today it is different. Man has brought about unnatural and adverse conditions in open waters. Pollution, cutting of forests, drainage and other detrimental factors must now be given careful consideration. The fish culturist no longer has an easy task to meet the demands made of him. Thirty years ago practically the entire output of marine and inland fishes by state and federal hatcheries was of the fry type. This contribution, coupled with natural reproduction, was ample to meet the demand. With the increase of population, rapid transportation and good roads, the demand has been multiplied many times. The need for expert fish culturists rather than those just engaged in the propagation of fish is vital now. The mere rearing of fish does not qualify an individual to assume the title of fish culturist. The field of a fish culturist extends to the output of fishes of the waters stocked. We are judged by the number of fishes removed from the waters rather than the numbers placed therein.

How much advancement has been made in the cardinal processes of fish culture? Are we able to obtain a better percentage of fertility in our egg-taking operations or hatch a better percentage from the eggs eyed? Has our fish cultural equipment been improved upon to any material extent? Do the foods we use now give any better results than those used thirty years ago? Have the remedial measures for control of diseases advanced to any appreciable extent?

In combating the several external fish diseases common to fishes at the average hatchery, such as gill trouble, *Ichthyophthirius, Gyrodactylus,* we are using salt, vinegar (acetic acid), carbonate of soda and copper sulphate, as was done years ago. Dr. H. S. Davis, Fish Pathologist of the U. S. Bureau of Fisheries, discovered the fish disease, *Columnaris,* and worked out a treatment of copper sulphate

effective under certain conditions. Few of the internal diseases, many of which have been identified, have a known cure as yet.

A recent experiment with one of the most formidable diseases with which the fish culturist has to contend, namely, Furunculosis, has led us to believe that we have at last discovered a means of stamping it out. One year has passed and there has been no sign of a recurrence of the disease at the station where the treatment was applied.

In pond fish culture, experiments have shown that the rearing of warm water fishes is primarily a matter of food supply. There is still much to be learned of food production for forage purposes. As of old, the staple food for warm water fishes is plankton, crustacea and larval insects. We have advocated the use of golden shiners indiscriminately for bass food, but experiments at some stations have taught us that the golden shiner has predatory tendencies. This is especially true at stations where the water supply is clear. Evidently, a more satisfactory forage minnow might be chosen.

Some fish culturists have declared that the adult minnow should never be introduced into a bass pond, but should be propagated only in separate ponds and the offspring introduced as small minnows. The subject of minnows and their use as forage fishes is one of great importance and should be cleared up, the facts definitely determined.

The size of ponds is still a controversial subject, some fish culturists advocating large ponds, while others favor small ones. Large ponds are favored where the brood fish are introduced and no attention paid the work until the pond is drawn. The smaller type requires more attention and is favored where positive control is desired. Both types are satisfactory. It all depends on the needs which they are to serve.

In the shipping of fish eggs, how far have we advanced in improved methods? Do we get better results than we did thirty years ago? Shipping equipment is practically the same except for some very minor modifications in size and construction of the shipping containers.

Has the fish cultural equipment in our trout hatcheries been improved or is it practically the same as thirty years ago, with a possible exception of added mechanical apparatus for pond cleaning purposes or some other minor equipment? The ponds in use are still of the same general type, except as modified to meet some purely local condition. This holds true of pond outlets also.

Circular ponds are not new, although credit should be given to E. W. Cobb and the late lamented John W. Titcomb for their successful experiments in Connecticut which resulted in some improvements in construction and brought to the attention of fish culturists certain advantages derived from their use. The Bureau of Fisheries is trying out this type of pond at the Leetown, W. Va., experimental station. One is in use at the LaCrosse, Wisconsin, station, where

adult fish are being held. This pond will be given a trial with fingerling trout next spring.

The fish foods that some of us believe are giving the best results today are the same ones used thirty years ago—liver and hearts. Generally speaking, we have found no foods better or more economical, all factors taken into consideration. Dry products, such as salmon eggs, clam heads, dry milk and others have been fed in combination with fresh meats with good results. But in the main, the same old foods are being used. Has it been determined whether the same foods will give the same results at each station or that the chemical constituents of the water at the several hatcheries scattered throughout the United States enter into the success or failure of certain foods?

The same general utility trough is still in use at the hatcheries. This trough is used for both hatching and rearing. There has been only a slight change in the troughs at stations where the stack tray system is used. The custom of using the same water eight to sixteen times is still a common practice. Some minor changes of equipment have been introduced at some of the hatcheries to satisfy some individual's desire rather than to affect an improvement.

Pollution, soil erosion, reforestation and all other problems bearing on open waters are matters of great importance and are a proper part of a fish culturist's business. While the fish culturist may be engaged in the propagation of fish, he is by no means an expert until he has at least a working knowledge of all outstanding matters pertaining to fish cultural problems.

The ultimate object of fish culture is to maintain and increase the supply of fishes in open waters as well as in the hatchery. Therefore, the fish culturist must be an expert in the propagation of fishes rather than one merely engaged in this field of work.

This paper is intended as a challenge to all engaged in fish cultural activities to get busy and do something for the improvement of the work in which we are all engaged so we may better meet the present day demands of more fish for more fishermen, regardless of adverse conditions which prevail at the present time in our open waters.

Discussion

DR. EMMELINE MOORE (New York): Mr. Culler mentioned that a method of combating furunculosis is under observation and that it seems to look towards success. I should like to inquire a little further about that method of stamping out the disease.

MR. CULLER: It is simply an application of the principle that I was taught many years ago by the dean of the service, Dr. George H. Seagle, that cleanliness is next to godliness in fish culture. We had a very bad outbreak of furunculosis at our Manchester, Iowa, station. The first thing we did was to eliminate all our brood stock; then we went clear through the water

supply of the entire system, using different things to combat the disease, particularly copper sulphate and permanganate of potash. All equipment—gloves, oilskins, and so on—was disinfected; anything that might carry the disease was given attention. Another thing we tried out—I do not know how good it is, although one of my friends is using it and thinks very well of it—was watercress in combination with liver and hearts in feeding the fish. At any rate we have eradicated furunculosis at Manchester.

DR. EMMELINE MOORE: That is very fine. However, cleanliness seems not to go the whole way, because the disease breaks out in some of our finest and cleanest streams and lakes. I was wondering if the observations made at the hatchery had been carried along further.

MR. CULLER: Possibly it was transmitted by some hatchery bred fish or from fish raised in the hatchery, and that while the outbreak was not apparent, some of the fish were carriers of the disease.

MR. ADAMS (New York): Do I understand that you speak of this method as being efficient in the control of furunculosis?

MR. CULLER: Absolutely.

MR. ADAMS: Killing all the brood stock?

MR. CULLER: Well, it is better to lose two years' output than to have attacks of the disease from time to time. My belief is that complete elimination of your parental stock is necessary in the eradication of the disease.

MR. ADAMS: Two or three times I have gone through this same cycle that Mr. Culler speaks about, and I was hoping that he had reference to some new magic that would enable us to deal with this disease not by disposing of the brood stock but perhaps by some other method of treatment.

MR. CULLER: I do not think anything but complete eradication or elimination of your brood stock will help.

DR. GREELEY (Michigan): Mr. Culler's very wide definition of fish culture induces me to make a few remarks. Fish culture alone does not stop with the propagation of fish. It is the duty of fish culturists to put things in the right places. With all the benefits that fish culture has brought about, we still must realize that fish culture gave us the German carp; it gave us bass in trout waters in many of the lakes of the Adirondacks, and it is accountable for many other mistakes which were made in the past in the belief that it would be helpful to put any kind of fish into any kind of waters. The introduction of the wrong fish in the wrong place can do more harm to the waters in which they are placed than almost anything else you can think of.

MR. ODELL (New York): Mr. Culler, I understand, said that the golden shiner had been shown to be predatory. I had always thought of that fish as almost entirely a vegetarian or a feeder on plankton organisms.

MR. CULLER: On the advice of different people we introduced the golden shiner into one of our ponds at the Manchester, Iowa, station. At a later stage smallmouth bass fry were introduced and when we drew the ponds there was nothing in them but the golden shiners, which were much larger than they had been. Golden shiners will take beef heart and liver just as readily

as the young trout do—I think some of the commissioners will bear me out in that statement.

DR. FISH (Washington, D. C.): If I may speak for someone who is absent, Dr. Wiebe, of Fairport, last spring told me that in answer to the question whether the golden shiner will attack black bass, he put golden shiners in aquaria, using ordinary Mississippi water, which is rather turbid, and then introduced bass fry. After a short time a small percentage of the bass disappeared, by actual count. Upon clearing the water by putting in well water, all the bass disappeared. I think that definitely proves the point that, experimentally anyhow, the golden shiner will eat fish. Whether that is true in nature, I do not know.

Through my affiliations I am primarily a scientist, but I have the interests of the fish culturist at heart. I believe both should work hand in hand, and for the most part they do; but they are both due for their share of criticism. No scientific discovery should be accepted at its face value until it has at least been verified and borne out in practice. However, the fish culturist is also due for criticism, as I see it. Fish culturists do not as a general thing apply the facts which they have at hand.

MR. WESTERMAN (Michigan): I wish merely to confirm Mr. Culler's statement with reference to the habits of the golden shiner. We have found in our bass work in Michigan that golden shiners have been predatory on numerous occasions, particularly at the Lydell hatchery near Grand Rapids.

SOME EFFECTS OF TEMPERATURE, AND THEIR RELATION TO FISH CULTURE

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That temperature plays a very important part in relation to all aspects of a fish culturist's interests and activities is well recognized by all. But the exact manner in which temperature acts, and how it influences the various phases of fish culture, this probably is not known. The notes following have been designed to throw a little light upon this most important subject. The preliminary publication of this work was by the Biological Board of Canada (1931).

Mr. J. W. Titcomb (1920, page 200) in some fish cultural notes presented a table showing "Variation in Growth of Trout under Different Qualities and Temperatures of Water." From this table (considering only the brook trout), it can be seen easily that temperature played an important part in the rate of growth of this species. A graph plotted from Titcomb's data reveals this better than the table (see Figure I). Trout in Source A grew better eventually than those in Source B, although for a time temperatures in Source B were higher than those of Source A, and there was, for this period, an acceleration of growth rate of Source B over that in Source A. The *average* temperature of Source A was stated to be 51° F., and that of Source B about 48° F., running higher in the summer and lower in the winter.

Dr. G. C. Embody, in the following year (1921) presented a paper "Concerning High Water Temperatures and Trout." In this paper, Dr. Embody showed that brook trout grew well, and did not exhibit undue mortality under temperature conditions as follows: "There were ten days in July and seven in August when it exceeded 77° and on three days it was above 80° F." Dr. Embody had made frequent temperature investigations of various streams, and had observed from these investigations "that it is an exception indeed to find one whose highest summer temperature does not exceed 75° F. in sections where brook trout commonly occur and apparently thrive."

The experiment then reported by Dr. Embody, in his succeeding paragraphs, is of the utmost interest and importance, considering again only the brook trout. He found the trout to become greatly distressed and to refuse to eat when a temperature of 83.3° F. was reached. There was no loss at this temperature—just the evidence of serious physiological upset; followed by recovery upon temperature dropping considerably. No loss occurred in succeeding days, with temperatures ranging up to 78.8° and 80.7° F., but the fish

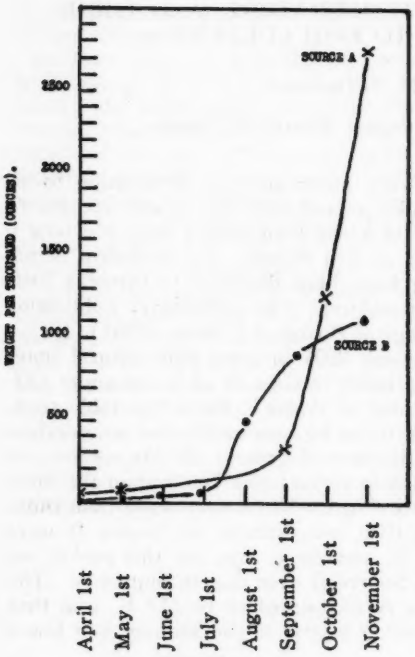

FIGURE 1

began to die at 84.2° (mortality 20%) [italics by present writer]: none died next day with a temperature of 82.4°; but the next day at 83.2° F., the loss was 100%.

These data of Mr. Titcomb's and of Dr. Embody's are of considerable interest in connection with the results of some experiments carried out at the Atlantic Biological Station, St. Andrews, N. B., and in the Florenceville, N. B., and Lake George (Yarmouth) N. S., hatcheries of the Canadian Department of Fisheries.

In these experiments, brook trout fingerlings, all less than a year in age, were used. The experiment consisted in heating from three to six fish in a small shallow pan at a standard rate of temperature increase (one degree Centigrade every five minutes) from the cold water of the stream to the point at which death ensued. In order to have the water of uniform temperature it was stirred by the thermometer. To have the water saturated with oxygen, the water in the pan was maintained at as low a level as possible.

Numerous experiments were carried out, and it was found that the fish when apparently normal and healthy, uniformly died at 29° C. (84.2° F.). Occasionally one would survive as long as 30° C. (86° F.). On the other hand, if the fish were not healthy (malnutrition, disease, etc.) mortality was observed to begin about 22° C. (71.6° F.), and to increase steadily until at 29° C., there would be no survivors.

At the same time, counts were made in every experiment of the respiratory rate, at given degree intervals. This was done with a stop-watch, finding the time required for fifteen respirations. This could easily be determined by counting the movements of the operculum, or of the lower jaw.

The results of these experiments were given in a report to the Biological Board of Canada, published in brief (M'Gonigle, 1931), and are presented in the following table by permission of the Board. This table is a summary of all the experiments which have been carried out to date. In the first column appears the temperature in degrees Centigrade, at which the observations were made; in the second column, the corresponding temperature in degrees Fahrenheit; in the third, is the respiratory rate as observed; in the fourth, is the average of the various rates for the temperatures where more than one reading was made.

TABLE I

Relation of Temperature and Respiratory Rate

I Temp. (Degrees C.)	II Temp. (Degrees F.)	III Resp. Rate (per min.)	IV Aver. Resp. (rate—per min.)
2	35.6	69	69
3	37.4	64	64
6	42.8	88	88
7	44.6	91	
		90	91
8	46.4	81	
		98	
		110	
		101	
		103	98
10	50.0	111	
		112	112
11	51.8	118	
		111	114
12	53.6	125	125
13	55.4	88	
		130	
		129	
		121	
		118	
		109	116
15	59.0	129	
		117	123
16	60.8	134	
		131	132
17	62.6	129	
		138	133
18	64.4	127	
		116	
		136	
		147	
		130	131
20	68.0	135	
		142	138
21	69.8	151	
		143	147
22	71.6	132	
		138	135
23	73.4	139	
		142	
		151	
		148	145
24	75.2	140	140
25	77.0	122	
		136	129
26	78.8	149	
		126	137
27	80.6	154	154
28	82.4	141	
		131	
		133	
		142	137

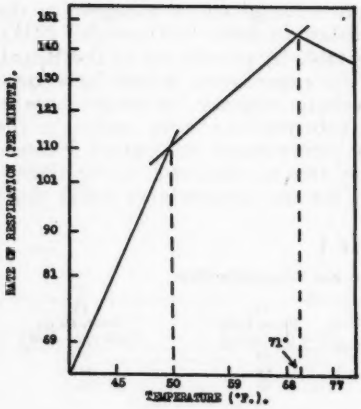

FIGURE 2.

In preparing the graph herewith (Figure 2) the results in the preceding table were treated mathematically, according to Crozier's formula, a modification of the more fundamental one of Arrhenius (J. Gen. Physiol. 1924-25, 7, 191). This treatment has not been shown in the table for the sake of simplicity; and for a similar reason, the graph has been also simplified, to correspond to the data in the table; the Centigrade temperature has not been used in the graph, although in the course of the investigation this was the scale used.

From an examination of the graph, it will be seen that there are three intersecting lines. These lines represent the relation between the rate of respiration per minute, and the temperature (degrees Fahrenheit), and it can be seen that the rate of respiration increases with rise of temperature, up to about 71° F., when it becomes irregular, but decreases in rate. At about 50° F., there is an intersection, below which point the rate of respiration increases more rapidly for a given rise of temperature than above it.

These results, read with the observations described above, of Titcomb and Embody, would seem to indicate that the physiological processes of brook trout undergo some sudden changes, at the temperatures indicated by the intersections of three lines found in Figure 2. Titcomb found considerably better growth above 50° F., and Embody found that in those sections of streams of which he determined temperatures, those which had much higher summer temperatures than 75° F. were not, unless exceptionally, places where these fishes were found. That the changes of the trout's physiological processes may be associated with some disturbance of the nervous system, at the upper of the three ranges, seems to be shown by several observations, of which the loss of balance, the irregular, gasping breathing, the sudden darkening in color, the distress, etc., observed to become increasingly evident with rise of temperature, are some examples.

What takes place in the lowest temperatures is best described by references to the works of an investigator, a quotation from which appears a little later in this paper (Battle, H. I.).

Embody's observations of death occurring at 84.2° F., in ponds in

more or less natural conditions would seem to be fully supported by the observations herein reported. It is of interest that in Embody's observations there is evidence of loss of resistance. At first, there was only distress manifested when the trout were exposed to 83.3° F., but after the first deaths at 84.2° F., death (100%) occurred when 83.3° F. was reached.

Before concluding these remarks, this would be an appropriate place to mention some other important temperature observations of interest to fish culturists. The first of these is a small table published by O. Haempel (1926) to show the relation between temperature, and oxygen requirements of trout, and carp, as follows:

TABLE III

Oxygen consumption, per kilogramme (2.2 lbs.) body weight; per 24 hours.		
Temperature	Trout (S. fario ?)	Carp (C. carpio)
10° C. (50.0° F.)	100 cc. (ca. 3 1-3 ozs.)	10-20 cc. (ca. 1-3—2-3, ozs.)
15° (59.0°)	220 cc. (ca. 7 ozs.)	
20° (68.0°)	460 cc. (ca. 15 ozs.)	
30° (86.0°)		150 cc. (ca. 5 ozs.)

Table III illustrates how much more rapidly a fish (or other cold-blooded animal) lives, with increasing temperatures, the amount of oxygen required being approximately doubled for each five degree Centigrade increase in temperature, somewhat more for carp, than the trout.

Another important publication (J. Gray, 1928) gives the number of days incubation of the eggs of *Salmo fario* (brown trout) from fertilization to hatching, when maintained at constant temperatures. At 35.7° F. 165 days were required, while at 54.0° F. only thirty-two were required. The number of days at the intervening temperatures followed a logarithmic curve, and is not therefore in strict accordance with the rule in general use among fish culturists of adding or taking off ten days for each degree plus or minus from 50° F. It was found that the more rapidly the fish were hatched, the smaller they were, and this is explained by the fact that the warmer it is, the faster the animal has to live and more food is required just to live than when colder; so less of the yolk can be used for the making of new tissues.

So far as known to the writer, little has been done to determine just how temperature acts upon these species used chiefly in fish cultural practise. However, some valuable work has been done upon the more readily available marine fishes, which have relatively short periods of incubation making them more suitable for experimental work of this nature; and attention is directed here especially to the work carried out at the Atlantic Biological Station, St. Andrews, N. B., by Dr. H. I. Battle.

This author has published several papers (see bibliography) which deal with the influence of temperature (and other factors) upon the

eggs and various tissues of certain fishes. The following excerpt from one of these papers (1929-3) will serve to indicate the method of action of temperature upon one (exceedingly important) phase of fish cultural activity, namely upon the eggs, which is of utmost importance to those shipping, and receiving shipped eggs.

This abstract will serve to show the extent of the author's investigations, for it forms part of her general conclusions. The original report may well be consulted by anyone interested further, since the detailed work, which it is quite impossible to quote here, should prove of great service to all fish culturists who on finding abnormal fish, abnormal hatching, and so forth, wish to know something of —"Why?"

> "Apparently then an organism may be considered as an aggregation of more or less susceptible individuals developing at their own particular rates. If, for some reason or other, these rates be retarded or accelerated, the relative gradient which they bear to one another will be changed. Similarly if they be slowed down a great deal for a short time as by placing at 0° C., and then be permitted to resume activities, they will no longer bear the same ration to one another. In either case, then, the relative proportions of the developing parts will as a result bear an abnormal relationship to each other. There are any number of means by which it is possible to show that abnormalities are due to an unbalancing of the proportional metabolic rates of developing organs. Different developmental stages of the rockling (*E. cimbrius*) vary in their susceptibility to high temperatures and hence must represent different types of metabolism. The magnitude of the developmental temperature coefficients indicate that both above and below the normal range the metabolic processes are abnormal. Temperature coefficients change in a manner indicative of the type of processes being carried on, for at high temperatures the magnitudes of the temperature coefficients for the duration of life of fish ova and larvae are very high, possibly due to pre-coagulation processes."

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FISH CULTURAL NOTES ON TROUT RAISING IN THE NEW JERSEY STATE FISH HATCHERY

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In previous papers by Dr. George C. Embody and the writer, published in the Transactions of this Society in 1925 and 1930, we discussed the advantages of rearing brook trout fingerlings from selected breeders.

In 1925 we selected twelve pairs of the finest and largest brook trout with an average length of twelve and one-half to thirteen inches. The average egg yield per female was 893, second spawning.

In 1930 we paired this same strain of trout, using the largest and finest females with males of the same size, keeping the eggs in separate compartments until they were hatched. The best group of four pairs of second spawning trout, measuring fourteen to sixteen and one-half inches, produced 9,440 green eggs, an average of 2,760 per female, an increase of 209% over 1925.

The second best group of three pairs of the second spawning breeders, measuring fourteen to fifteen and three-quarter inches, produced 6,688 green eggs, an average of 2,229 per female, an increase of 149% over 1925.

In 1931 the best group of eight pairs of first spawning breeders, measuring twelve and one-half to fourteen and one-quarter inches, produced 15,324 green eggs, an average of 1,915 per female, an increase of 114% over 1925.

As soon as the young trout attain a size of two to four inches we run them through the sorting boxes and keep only the three and four inch fish. The two inch trout that are the runts are immediately planted. By getting rid of the runts and rearing only the more rapidly growing fish we utilize the food more efficiently.

By using every precaution during the past three years we have been able to greatly reduce the food cost per pound. In 1929-30 it took 837,374 pounds of food to produce and distribute 446,882 trout weighing approximately 151,642 pounds. The average cost of food per pound was $.048. That year it took five and one-half pounds of food to make a pound of trout at an average cost of $.264.

In 1930-31 it took 847,668 pounds of food to produce and distribute 467,390 trout weighing approximately 210,625 pounds. The average cost of food per pound was $.047. It took four pounds of food to make one pound of trout at an average cost of $.189.

In 1931-32 it took 848,024 pounds of food to produce and distribute 506,667 trout weighing approximately 240,085 pounds. The

average cost of food per pound was $.04. It took three and eight-tenths pounds of food to make one pound of trout at an average cost of $.152 per pound.

1929-1930

KIND, NUMBER OF POUNDS AND COST OF FOOD USED DURING THE YEAR

Lbs.	Kind	Cost per lb.		Total Cost
33,768	beef lungs	.0382		$1,290.26
35,228	beef livers	.1275	.1282	4,503.58
78,695	pork melts	.0382	.0425	3,223.93
86,787	beef melts	.0382	.0380	3,303.46
254,053	sheep plux	.0745	.0595	16,675.82
231,232	herring-mackerel	.03	.03½	7,580.19
40,000	shrimp bran	50.00 per ton		1,250.00
40,000	Struven's fish meal	70.00 " "		1,400.00
10,000	condensed buttermilk	78.00 " "		389.99
1,717	cod liver oil	1.00	1.22 per gal.	215.79
25,874	milk	.08 per quart		750.30
837,374				$40,603.32

NUMBER, SIZE AND WEIGHT OF FISH DISTRIBUTED DURING THE YEAR

No.		Length		Weight
9,850	brook trout	6- 7 inches	11 to a lb.	895 lbs.
9,265	" "	7- 9 "	4 " " "	2,316 "
14,920	" "	8-10 "	3 " " "	4,973 "
13,650	" "	8-12 "	2½ " " "	5,460 "
800	" "	10-14 "	¾ " " "	600 "
2,067	" "	12-14 "	1¼ " " "	2,583 "
96,635	brown trout	7- 9 "	4 " " "	24,158 "
43,600	" "	8-12 "	2½ " " "	17,440 "
20,000	" "	9-12 "	2½ " " "	8,000 "
23,000	" "	10-12 "	2 " " "	12,500 "
1,750	" "	12-18 "	2 lbs. each	3,500 "
13,800	loch leven trout	6- 9 "	7 to a lb.	1,971 "
110,675	rainbow trout	7- 9 "	4 " " "	27,673 "
5,500	" "	8-10 "	3 " " "	1,833 "
54,350	" "	9-11 "	2½ " " "	13,740 "
10,000	" "	9-12 "	2½ " " "	4,000 "
25,000	" "	10-12 "	2 " " "	12,500 "
10,000	" "	10-14 "	¾ " " "	7,500 "
446,882				151,642 lbs.

5½ lbs. food to make one pound fish.
$.048 average cost per lb. for fish food.
26.4 cents average cost per lb. of food to make one pound of trout.

1930-1931

KIND, NUMBER OF POUNDS AND COST OF FOOD USED DURING THE YEAR

Lbs.	Kind	Cost per lb.		Total Cost
1,682	cod liver oil	1.20	1.12 per gal.	$246.24
111,251	pork melts	.0420 per lb.		4,686.46
112,808	beef melts	.0420 " "		4,755.34
25,905	beef livers	.1275	.1337	3,431.94
331,345	sheep plux	.0547		18,257.82
50	dried buttermilk	.098		4.90
237,912	herring	.03½		8,327.09
25,745	milk	.06-.08 per qt.		750.60
847,668				$40,460.39

NUMBER, SIZE AND WEIGHT OF TROUT DISTRIBUTED DURING THE YEAR

No.		Length		Weight
20,365	brook trout	6- 8 inches	7 to a lb.	2,909 lbs.
28,625	" "	7- 9 "	4 " " "	7,156 "
60,740	" "	8-11 "	3 " " "	20,246 "
12,310	" "	9-11 "	2½ " " "	4,924 "
982	" "	12-15 "	1½ " " "	1,473 "
42,075	brown trout	6- 9 "	7 " " "	6,010 "
19,350	" "	7- 9 "	4 " " "	4,837 "
40,532	" "	8-10 "	3 " " "	13,510 "
4,000	" "	8-12 "	2½ " " "	1,600 "
20,400	" "	10-12 "	2 " " "	10,200 "
9,835	" "	10-14 "	¾ " " "	7,377 "
47	" "	14-18 "	2 lbs. each	94 "
417	" "	16-20 "	3 to a lb.	1,251 "
500	rainbow trout	7- 9 "	4 " " "	125 "
63,587	" "	8-10 "	3 " " "	21,195 "
143,625	" "	10-14 "	¾ " " "	107,718 "
467,390				210,625 lbs.

4 lbs. food to make one pound fish.
$.047 average cost per pound for fish food.
18.9 cents average cost per pound for fish food to make one pound of trout.

KIND, NUMBER OF POUNDS AND COST OF FOOD USED DURING THE YEAR 1931-32

Lbs.	Kind	Cost per lb.	Total Cost
369,817	Sheep plux	.0446	$15,961.67
253,919	herring (marine)	.03½	8,886.86
56,850	beef melts	.0373	2,131.94
114,801	pork melts	.0387	4,442.75
3,228	dyed beef livers	.0625	201.76
15,290	fresh beef livers	.0798	1,221.14
19,593	milk	.06	570.00
3,404	cod liver oil	.80-1.12-1.05 per gal.	443.88
100	Kinney's Fry Food	.08	8.00
2,000	bean meal	.0125	25.00
8,022	Balto	.0639	499.57
848,024			$34,392.57

NUMBER, SIZE AND WEIGHT OF TROUT DISTRIBUTED DURING THE YEAR

No.		Length		Weight
28,700	brook trout	6- 7 inches	11 to a lb.	2,609 lbs.
2,900	" "	6- 8 "	7 " " "	414 "
26,475	" "	7- 9 "	4 " " "	26,475 "
31,305	" "	8-10 "	3 " " "	10,435 "
4,925	" "	10-12 "	2 " " "	2,462 "
1,890	" "	10-14 "	¾ " " "	1,416 "
1,250	" "	12-14 "	1 lb. each	1,250 "
475	" "	14-17 "	2 " "	950 "
7,000	brown trout	6- 8 "	7 to a lb.	1,000 "
5,700	" "	7 -9 "	4 " " "	1,425 "
117,157	" "	8-10 "	3 " " "	39,052 "
82,916	" "	10-12 "	2 " " "	26,458 "
17,290	" "	12-14 "	1¼ " " "	21,612 "
579	" "	14-18 "	2 lbs. each	1,158 "
560	" "	16-20 "	2 " "	1,120 "
9,000	rainbow trout	6- 8 "	7 to a lb.	1,285 "
101,240	" "	8-10 "	3 " " "	33,746 "
53,255	" "	10-12 "	2 " " "	26,627 "
28,975	" "	10-14 "	¾ lb. each	21,729 "
15,000	" "	12-14 "	1½ to a lb.	18,750 "
75	" "	12-16 "	1½ " " "	112 "
506,667				240,085 lbs.

3.8 pounds food to make a pound fish.
$.04 average cost per pound for fish food.
15.2 cents average cost per pound for fish food to make a pound of trout.

Discussion

MR. COBB (Connecticut): The one question that is of more interest to me than any other in regard to this selective breeding is this: Are you able, in selective breeding, to breed up one advantage, two, three or more, or do you in building up one encounter dangers with respect to others? If you develop a fast growing fish, do you maintain your health, and can you increase your productiveness without reducing the value of your fish in other respects?

MR. HAYFORD: I tried to make it clear that by selective breeding we are getting a much faster growing fish and cutting off practically 33% of the time in getting it to the size we wanted; and by eliminating the feeding of fish that later died we greatly reduced our cost. We have gained three pounds after about ten years' work. At first we lost practically all the fingerlings, but by the time the third generation was reached we had greatly increased the percentage of survival. Then after developing the fast-growing strain we lost out on the hatchability of the eggs; but that was not so much the fault of the fish as it was the improper pairing of the male and female. As soon as we corrected that we came through with a much better hatch.

MR. COBB: Then at the same time you have been able to increase your growth and your productivity, and decrease your mortality?

MR. HAYFORD: We have had all these three purposes in view, but as fast as we got by with one we would have to go back and correct others. There were a lot of factors that entered into that, such as parasites, etc.; you had to follow them all the way through with a microscope to maintain your growths. The first year we used no precautions whatever; we took 43,000 fry, and if they wanted to die we let them die. We did not clean the ponds or anything else, and if as a result we had only one pair, we had the toughest pair, and that is what we wanted.

MR. COBB: If I understand you aright, in sorting your fish you pick out what you call the runts and eliminate those most susceptible to disease. I have been told a great many times during my lifetime that disease might be brought about by overfeeding, and overfeeding naturally increases the growth; that by keeping our feeding down and keeping the fish from growing too fast and becoming too fleshy we would eliminate some of this disease. I do not know which is right and I just wanted to bring that matter up. Are the rapid growing fish more or less susceptible to disease?

MR. FOLLETT (Michigan): It may be said of all forms of animal life in captivity, aquatic or terrestrial, that if they are overfed they become unhealthy.

MR. COBB: I have found that in experimental work on fish one can learn a great deal by following the experimental work on domestic animals. When by proper breeding we build up a tremendous production in domestic animals—in milk and cream, for instance—it is almost always accompanied by disease.

MR. GORDON (Washington, D. C.): A question came to your Secretary some time ago which was in the nature of a criticism on the part of one of the members: A local sportsman said his fish, while they had grown very rapidly, were not really fit to be stocked in the ordinary streams of that par-

ticular state because of their inability to buck the current of the streams. He claimed that the cause of this was not in the muscular structure but in the bone structure of the fish; that the bones of his trout were soft and therefore they were unfit for stocking purposes. I should like to know whether there is anyone in the audience who has ever made a study of bone structure and who can really testify on this subject.

MR. COBB: I cannot answer that question intelligently, but I would say that Dr. McCay, who has been very closely associated with Dr. Embody, has been working along that line, and I think Dr. Embody could give us some light on the subject.

DR. EMBODY (New York): I do not think I can give you anything very definite along that line. In the report made by Dr. McCay in 1931, published in the Transactions of the Society for that year, you will find an account of his investigations covering the subject in question. Dr. McCay went into the matter in some detail, and I have not thoroughly digested his report, but my impression is that the trout he fed upon mixtures very rich in mineral substances did not show bone structure very different from that of fish fed upon a light mineral ration. He was under the impression, I gather from his paper of last year, that trout might absorb mineral matter from the water, as was pointed out by Dr. Davis several years ago, and that mineral matter in excess of what would be found in ordinary hatchery food did not appear to produce a superior skeletal structure. I am sure Dr. McCay would be glad to answer any inquiries you might address to him.

DR. DAVIS (Washington, D. C.): In regard to the problem that is presented by furunculosis, of course there are obviously two courses open: either to eradicate the disease entirely or to try to build up a more or less immune strain of fish and in that way alleviate the effects of the disease. Eradication is of course a very drastic method. Prior to the experience with furunculosis at the Manchester station, the Bureau had eradicated the disease at a cooperative station which we had been operating at Barneveld, New York, in connection with the local chapter of the Izaak Walton League. The records showed that at this station, which was formerly a commercial hatchery, furunculosis had prevailed for a considerable length of time—at least ten or fifteen years. By getting rid of all the fish and adopting very thorough disinfecting methods the disease has been entirely eradicated and although the station has been operated for several years since there has been no recurrence of it. On the other hand, it should be very distinctly emphasized that this cannot be done if you are going to operate your hatchery continuously.

Experiments by European investigators have shown conclusively that the bacteria which is the cause of this disease are carried by fish which show no evidence of disease at all; you have carriers just as you have in typhoid and other such diseases. So that the only possible way the disease can be eradicated from a hatchery is by getting rid of all the fish and by adopting very thorough disinfection methods. In many cases that is hardly feasible. Unfortunately the disease is becoming more and more widespread in this country, and I am not sure that in time we will not get to the position in

which Germany finds itself at the present time, where it is said there is not a single trout hatchery in the country in which furunculosis does not occur. There, however, it is said that they do not look upon it as a particularly important problem; they take it as one of the things that the fish culturists have to contend with, and they manage to get along pretty well in spite of the fact that they do have losses from the disease. A certain degree of immunity to the disease is built up in a hatchery as a result of its recurrence year after year; the more susceptible fish are killed and therefore are not perpetuated. As Mr. Hayford has said, we are trying to build up a strain which we hope will be practically immune from the disease.

MR. FOLLETT: Would you tell us, Dr. Davis, something about the origin of this disease?

DR. DAVIS: We know more about furunculosis than we do about any other disease of fish, because it has been studied a great deal in Europe, though not so much in this country. We know it is caused by small, rod-shaped bacteria which occur primarily in the blood and are carried in the blood stream to all parts of the body. Under certain conditions the bacteria may become localized in certain tissues, especially those which have an abundant blood supply, such as the liver, or the spleen; and very often it gets in the muscles, especially at the base of the fins. Disintegration of the muscular tissue follows; the blood vessels go to pieces and you get the bloody pus-like condition which is characteristic of the disease. That material carries an immense number of bacteria, and it goes out in the water and affects other fish. There is a difference of opinion as to whether uninjured fish can contract the disease. Some contend that the disease is mainly carried through the intestinal tract; others hold it is also contracted through slight abrasions or injuries to the fish. I am rather inclined to think there is probably more or less truth in both these contentions.

MR. THOMPSON (Massachusetts): Do you consider there is any danger of transferring disease to the fish through the feeding of diseased beef liver?

DR. DAVIS: No; there are no parasites, so far as we know, that occur in both cattle and fish. I should think there would be no danger in that respect.

MR. FOLLETT: Do you think tubercular liver would be wholesome to feed the trout?

DR. DAVIS: Well, if it is not too badly infected. It has been shown that fish have tuberculosis, but on the other hand it has also been shown that the tubercular bacteria which occur in fish are in some respects different from those which occur in mammals. It is the general belief of bacteriologists that the transfer of tuberculosis from one species of animal to another which is not closely related to it does not occur very frequently under natural conditions.

MR. FOLLETT: But it is possible?

DR. DAVIS: It is possible, yes, theoretically.

MR. MARKUS (New York): Has it been established whether drying or sunlight would have any effect on this apparently water borne furunculosis bacteria?

DR. DAVIS: Yes, when exposed to drying or sunlight it is killed very quickly.

Investigations also show that in pure water, such as spring water, under any ordinary circumstances the bacteria are unable to live more than two or three weeks. Some German investigators claim that when it gets into the muddy bottoms of ponds it may live there for months. It has been shown that in dark, damp lakes the bacteria may live as long as a year, but in dry lakes fully exposed to the sunlight it dies off very quickly, because it is a non-spoliating form.

MR. LANGLOIS (Michigan): Did Mr. Hayford use the same food through these three years?

MR. HAYFORD: We used practically the same combinations of food with some variations. We have selected each year about 200 pairs of the very best brook trout, and kept the records of each one separately; then just before they hatched we discarded all those that had heavy mortality eggs or were not up to standard.

OBSERVATIONS ON PLANTINGS OF FINGERLING RAINBOW, BROWN, AND BROOK TROUT FROM CIRCULAR POOLS

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The purpose of this study was to observe the behavior of 3" to 4" fingerling trout immediately after they were planted in suitable streams from circular pools.

Rainbow Trout

Plantings of rainbow trout for experimental purposes were first made on August 10, when 700 rainbow trout, averaging 76.45 mm. in length and weighing 6.23 grams each, were placed in a pool about 30 ft. long, 15 ft. wide at the widest point, and from a few inches to two and a half feet deep in Davis' Creek near Leesburg, Va. The deepest part of the pool was at the foot of gravel-bottomed riffles. Water cress bordered both sides, and at the foot of the pool were more riffles, about half gravel, half rock. The volume of flow at this point was estimated at about 1,000 gallons per minute.

An observer was stationed at the foot of the first large pool about 142 ft. upstream where the bottom was clearly visible. Another observer was stationed in the same manner at about the same distance downstream, while a third watched the pool in which the planting was made. All had notebooks, watches, and pencils at hand.

When first liberated, the trout formed large schools of very actively swimming fish. Small schools of a half-dozen to fifteen or twenty fish would occasionally drop down from the larger schools, which remained near the head of the pool. Individual excursions were rare and all of the trout avoided the natural shelter of water cress at the borders of the pool. These trout swam in schools in the undecided manner in which chickens maneuver in front of an automobile.

The trout were liberated at 10:42 A. M. and four minutes later began dropping down to the foot of the pool and into the riffles below. Schools of three to fifteen fish left the pool in rapid succession until about 11:20, when the rate abated considerably after 164 fish had disappeared in the riffles. The station was abandoned at 11:49 A. M. with a large number of trout still in the pool. Most of these were in the deeper water at the head of the pool.

In leaving the pool the fish followed a leader, but leadership passed from one to another. Going down the pool, they would occasionally whirl about and face the current, but left the pool head first or sideways, hesitating for a moment at the riffles.

In this planting the first rise to the surface, presumably for food, occurred at 11:05 A. M. Thereafter rises became more frequent until between 11:41 and 11:44 seventeen were noted in the three minute period. At 11:34 a grasshopper fell upon the water and several struck at it, but the insect was too large for them to handle. When a bird flew overhead, the schools dispersed laterally toward the shores, but immediately re-united.

At the first station, B-1, about 150 ft. below the pool in which the trout were planted, the appearance of the first arrivals of downstream jaunters was noted at 11:00 A. M. By 11:05, four trout had passed this station, and a new station about the same distance downstream was taken. Eight trout had passed this station, B-2, by 11:50. Station B-3 was at the foot of a rather long and particularly desirable pool, and although trout were observed in it, none had passed the observer when the station was abandoned at 12:30. The fish at all times appeared very alert and darted rapidly about the pool.

No fish passed the observer at station A-1 at the lower end of the first pool above that in which the trout were originally planted before he left at 12:20 P. M.

Upon returning to the pool at 10:00 A. M. the following day a cautious approach was rewarded after seven and a half minutes with the sight of a trout which rose to the surface for food. At 10:14 a rainbow trout about eight inches, already present in the creek, frightened a number of young trout down the pool, where they hurried to cover under the cress.

Ascending the creek slowly for about a quarter of a mile, the observer saw no trout. The same was true along a similar section of stream below station B-3. However, two Leetown trout were captured in the pool above station A-1 later in the afternoon of the same day.

Upon seining the planted pool at 3:20 P. M., August 11, about fifty to sixty trout were obtained in one haul and sixteen of these were examined to determine how many had been feeding. All had taken food consisting of mayfly nymphs, water boatmen, shrimps, and midgefly larvae.

In following up this planting further, the stream was revisited August 22. A large percentage of the trout placed in the creek, although in excellent condition otherwise, had nipped dorsal fins, acquired at the hatchery. The nipped dorsal condition made it possible to identify our fish from others in the stream. On August 22, fourteen Leetown trout obtained by seining averaged 7.34 grams in weight, an increase of one gram in the twelve days that had elapsed since they were planted. A change in color was also apparent. When placed in the creek their fins were gray, and a deep grayish purple cast was present on sides and gill flaps. No pink stripe was present along the lateral line. However, by August 22, the stream fish had acquired orange-pink fins tipped with white; distinct pink lateral

stripes, and had become lighter in color, losing the original dark purple and gray shades.

On September 2, forty-eight specimens from the creek averaged 9.55 grams in weight. Twenty-five of these fish could be recognized by the nipped dorsals, which in several cases had grown out to the normal condition, though the regenerated tissue lacked the pigments of the normal fin. The average length of the Leetown trout was 86.32 mm., an increase of about 9.8 mm. in twenty-three days. During the eleven day interval since the last visit to the stream, the color in the fins had intensified, and the pink of the lateral lines had deepened to a rose color. A golden sheen had developed above and below the lateral line outside the stripe area.

Attention is called to the fact that the experimental stream was very rich in food and bordered for about two-thirds of its length with water cress which harbored large numbers of fresh water shrimp. The riffles were particularly productive of mayfly nymphs.

On August 16, 300 rainbow trout, weighing 10.8 grams each, from a nursery pond at Catoctin, Md., were planted in Davis Creek to compare the reactions of trout reared in a comparatively quiet water nursery pond with those of the circular pool fish. As before, an observer was stationed at the foot of the first pool above and near the foot of the pool below, while a third watched the pool in which the fish were planted. Very soon after planting the fish began leaving the pool headed downstream in small schools of from three to about fifteen fish. They moved more slowly than the circular pool fish and hesitated at the riffles longer before descending to the pool below. Otherwise their behavior and manner of distribution was similar to that of the circular pool trout planted earlier upstream. The first of these fish broke the surface for food eleven minutes after planting. Thereafter rises occurred frequently. The first trout on its way downstream passed station B-1 fourteen minutes after planting, but no more passed during the next half-hour. At station A-1 upstream, two came by within three minutes after planting, and four had passed the station within eighteen minutes. No trout were seen during the next half hour at station A-2 about 100 ft. farther downstream.

Brown Trout

On August 26, 360 brown trout, averaging 73.24 mm. in length and weighing 6.6 grams each, were planted near Shepherdstown, W. Va., in a stream pool with riffles a short distance above and below. The riffles were over a marl or dirt bottom and were bordered with Chara and water cress. The pool in which these fish were liberated was about 30 ft. in length, 7 ft. wide, and from a few inches to about 2½ ft. deep. The bottom was composed of silt or muck. The pool was bordered with grass at the lower end and with water cress at its head.

When the trout were planted at 2:25 P. M., they swam in a body to the head of the pool, and several continued on upstream. Soon many dropped down the pool and scattered throughout its central area.

The first trout appeared at station A-1, about 75 ft. upstream, within three minutes; and four passed this station within five minutes. At the new station, A-2, about 50 ft. above, four fish appeared within twenty minutes. These trout continued upstream until they reached a partial weed barrier about 125 yards above.

During this time, no trout were observed to leave the pool downstream. However, a trout appeared opposite station B-1, fifty feet below the pool, thirty-five minutes after planting. It required an hour and twelve minutes for four fish to reach this station, and one hour and fifty-five minutes for five trout to reach station B-2, about 200 ft. below the planted pool.

The brown trout which did not leave the pool almost immediately remained in it. After about an hour, in which the trout were scattered quite uniformly through the middle of the pool, there was a tendency to gather toward the upper and lower end. They began striking at passing objects within a few minutes after planting, and two fish were observed seizing something, probably food, off the bottom. On the whole, these fish seemed alert as to what was passing on the surface and appeared to hold their heads somewhat above a level plane. The observers' presence and movements on the bank were almost ignored by the brown trout in contrast to the reactions of the rainbows. Raising an arm quickly would cause them to dart away temporarily, however. Upon leaving the planted pool one hour and fifty-five minutes after planting, 170 trout were counted.

Upon approaching the pool cautiously the following morning, a green heron that was standing upon one end of a log that laid partly submerged across the middle of the pool was seen to seize a trout back of the head, turn it in its bill and swallow it head first. An examination of the pool showed seventy-six brown trout in widely spaced schools near the bottom. Upon testing them by raising an arm quickly, they were found to be more wild and alert, but could not be frightened from the pool. An attempt to frighten them out of the pool by wading down from the head through the center failed since the trout hurried to the foot of the pool, reversed their direction quickly and came back between the observer's legs.

An examination of the creek above and below the planted pool on August 27 showed the presence of trout about 200 yards upstream and 250 yards downstream. These fish had become very wild.

On August 29, a cautious approach to the pool disturbed a large rainbow trout from beneath a half submerged log. Only a few brown trout remained in the pool at this time, but specimens were seen at many points up and down the stream.

On September 9, two weeks after planting, twelve specimens were

captured from the creek that averaged 7.13 grams, indicating an increase in weight during this period. An examination for changes in physical appearance showed that their fins had taken on a deeper yellow color, very definite orange spots had appeared on their sides, and two specimens had distinct red spots.

Brook Trout

At 1:58 P. M., August 29, 648 brook trout averaging 84.42 mm. in length and 7.73 grams in weight were liberated in Turkey Run near Middleway, W. Va., in a pool about 60 ft. long, 15 ft. wide, and 20″ deep at the deepest point. The stream of water coming into the head of the pool was divided by a bed of water cress. The bottom of the pool and above the stream was composed mainly of black mud and organic debris. Below the pool there was a succession of gravel-bottomed riffles and shallow pools for at least a quarter of a mile. Vegetation, except at the upper end of the pool, was scanty, and occurred only along the shores.

Immediately after liberation at the head of the pool, the fish formed two large schools, one of which moved to the edge of the cress at the head of the pool while the other swam across to the foot of the riffles.

Both of these schools had dropped farther down the pool within twenty minutes after planting and had broken up into a few small schools. Rises to the surface for food occurred within ten minutes after planting.

The first upstream migrating fish did not appear at station A-1, located about 50 ft. upstream above the bed of water cress, until 2:50 P. M., almost an hour after planting. This fish appeared very wild, and darted in and out of the vegetation. Two more arrived at 3:00 P. M. and shortly thereafter one was noted chasing a young dace with apparent intent on a meal. A few minutes before two trout in the planted pool had also been observed pursuing young dace.

The pool was revisited the following morning at 9:15. Soon after arrival a trout rose from a small school to strike twice at a water strider that easily escaped. While watching this school a trout was seen to seize something from the bottom, undoubtedly food. In moving from the foot to the head of the pool, four schools were found containing from 27 to 100 or more trout. They were located at the bottom in mid-pool where there was a perceptible current. It was estimated that 200 trout were present over the exposed bottom area of the pool. They had become lighter in color, and were difficult to see at first over the light, current-swept marl bottom where they hovered in seeming preference to the black mud and muck bottom elsewhere in the pool. Their movements on being alarmed were very quick, as were also their rises to the surface for food.

Revisiting the pool on September 1, at 9:50 A. M., a school of

forty-two trout was found near the bottom about 20 ft. above the foot of the pool. At about the same distance from the head of the pool there was a larger school containing at least fifty fish. A few stragglers were seen at other points. These were very wild and quickly swam out of sight.

On September 2, the pool was seined and the thirty-six trout captured in one haul averaged 5.88 grams in weight, indicating a loss of about 1.85 grams in the four days since planting. An examination of the stomachs of sixteen of these fish revealed that all had consumed food, consisting chiefly of sow bugs (Asellidae), and water boatmen (Corixidae).

An examination of the creek for about a quarter of a mile downstream at this time did not reveal a single trout. No examination was made above the pool because of its marshy nature.

Another planting of brook trout from the same circular pool was made in a pool in Evitts Run near Charles Town, W. Va., on August 30, at 2:10 P. M. Briefly their movements consisted of frequent excursions, in schools, to the foot of the pool. Up until 3:30 P. M. none had left to go downstream. At 2:45 a beetle which had fallen upon the surface of the pool was struck at three times but was too large for these fish to handle.

At station A-1, about 75 ft. upstream, with swift water intervening between the station and the planted pool, a trout appeared seven minutes after planting. Six more appeared a moment later and stayed in the locality until 3:30, when observations were abandoned. During this time individuals were observed rising to the surface for food, and one chased a dace.

A portion of the same lot of brook trout was placed in the head spring at Engle's farm, where a large quiet pool existed. Three schools were formed which remained in the vicinity of the main spring. Not more than five minutes after planting one trout seized a small minnow, and others rose to the surface for food. One small school gathered in the limestone crevice where the main volume of water emerged from the ground, and the following morning at 11:30, a portion of the school was still there. A large female water snake, taken at the same place and killed, had two trout in its digestive tract.

The above data indicates that trout should be well scattered along a stream in planting, and that the head spring is probably one of the most dangerous places to plant them.

SUMMARY OF FINDINGS

1. Gregariousness has been a characteristic of all species of trout planted from the circular pools. The probability that the trout in the circular pools use one another as points of reference while swimming is

not supported by observations of trout planted from an ordinary pool, unless they also use one another as points of reference.

2. The circular pool fish begin taking natural food almost immediately after planting.

3. Changes in color undoubtedly due to natural food are noticeable within two weeks after planting.

4. Rainbow trout distributed themselves from the planted pool more quickly downstream than upstream, while the opposite was true with brook and brown trout.

5. In general, fingerling trout show a tendency to remain for a considerable length of time in the pool in which they were liberated. When thus congregated they are quickly located by their natural enemies.

Discussion

MR. E. L. WICKLIFF (Ohio): What was the natural food of the trout that caused them to color after you put them out?

MR. EUGENE SURBER: Upon examining sixteen rainbow trout the day after planting, we found that they had been eating freshwater shrimp—Gammarus; mayfly nymphs, water boatmen and midge-fly larvae.

MR. COBB (Connecticut): Did you find any nipped fins in the trout in the circular ponds where the circular ponds were not overcrowded?

MR. EUGENE SURBER: Yes. We carried 20,000 trout in a fifteen foot pool all summer—a pool fifteen feet in diameter and eighteen inches deep—and about 97% of these trout had nipped fins. In the pool next to it there were about 6,000 rainbow trout, and as I recall it there were about 60% with nipped fins. In another pool there were 15,000 rainbows that we had fed more heavily to try to determine whether under-feeding was actually responsible for the nipped condition. The percentage was considerably lower than in the pool that had the 20,000 fish, so I think it probable that overcrowding and under feeding are the two factors responsible for the nipped condition.

MR. COBB: You spoke of the planting of trout in the pools. That is a common expression among sportsmen—that the fish were planted in certain pools. Don't you find it more desirable in planting trout to plant them in the more rapid waters between the pools?

MR. EUGENE SURBER: Yes, I think that would be much more desirable. But we wanted to get their reactions from the pools—to find out just how long they would stay there together; how they would behave; whether their tendency was to work as rapidly upstream as downstream, or vice versa.

MR. COBB: That is what I thought, but I wanted to bring out that point and see how you stood on it. It might be understood from some of these papers that *it is customary to plant in pools, but it is better to plant in more rapid waters.*

MR. EUGENE SURBER: I should think it would be much more desirable to plant fish in rapid waters; they would certainly distribute themselves much more rapidly than when planted in a pool. I have mentioned the changes in color

in fish after planting. This summer we fed a lot of brook trout and a lot of rainbow trout on sow-bugs alone, and we found that within a very short time the brook trout became the most highly colored fish in the hatchery. They do not have the color all over their body that the brook trout fed on beef liver and salmon eggs do, but their color was much more vivid; the fins were very red and the spots on their sides stood out very distinctly. The rainbow trout fed on sow-bugs also showed a quick change in color and were very pretty.

DR. AGERSBORG (New Hampshire): Were there any variations in temperature where your studies were carried on?

MR. EUGENE SURBER: No detailed observations were made on temperature, but in all cases the plantings were made within a mile of the head springs, and the temperatures were relatively low.

MR. WEBSTER (Wisconsin): You spoke of nipped fins; what fins do you mean were nipped?

MR. EUGENE SURBER: The dorsal fins alone were the nipped fins. I thought at first that the nipped condition might be due to parasites, but a thorough examination did not reveal the presence of any parasite.

SOME THINGS WE THINK WE HAVE LEARNED AT YORK POND

A. H. Dinsmore

United States Bureau of Fisheries, St. Johnsbury, Vt.

The work at the York Pond brook trout brood station, described and illustrated at the Hartford meeting in 1927, has afforded an opportunity for observations and led to certain conclusions which may be of interest to those engaged in trout culture.

In a climate such as that of New England, anchor ice presents a tremendous difficulty in the control of flowing water and, it would seem probable, does vast injury to stream life. We early learned that, in building artificial channels, a grade of two inches to the hundred feet obviates all difficulty from this source. Since the opening of a large canal, on July 1st, a few records of temperature indicate that a brook of gentle flow warms to a lesser degree on a hot day than does one which falls rapidly over a rocky bed. It seems obvious, then, that a brook of gentle flow, free of anchor ice in winter and vegetated, because unscoured by floods, is best for fish life. The application of this principle is often possible for stream improvement.

Some observations, not yet conclusive, indicate that as domesticated trout advance in age there is a loss in the fertility of their eggs. Since, however, we have been fairly successful in using the normal salt solution in removing infertile eggs, and a single fish, yielding 3,000 to 4,000 eggs, can be fed a year at lower cost than a sufficient number of small fish can be produced for similar yield, we have been holding female fish for life. Our experience in planting such fish is that the plug fisherman gets them all in a few days and no permanent improvement results.

Reluctant as we are to admit it, it now seems certain that the offspring of trout held for generations under domestication make much more rapid growth than do trout bred directly from wild stock. Our brood stock is now from two to five generations from wild fish. The brood fish of each generation have been carefully selected from the most rapid growing fingerlings and marked improvement has been attained. That we have not yet reached our goal seems evident from the results of the present season.

Last winter, with approximately a million York Pond eggs, we handled, under precisely similar conditions, 100,000 commercial eggs from fish which probably had received no strain of wild blood in twenty-five successive generations. Of the commercial lot approximately 65% were lost during the egg and sac stages. The losses on

the York Pond lot, during these stages, were negligible. The commercial fish remaining at the beginning of the feeding period have been held separately under conditions as nearly as possible like those applied to ours. From the very start, they took feed much more freely than ours with a consequent much more rapid growth. The difference in the action of the two lots is as great as one would expect in that between domesticated cattle and wild deer. The former congregate on the approach of the attendant and take the feed as do adult trout, the latter show fear months after feeding begins and take their food, for the most part, only as it floats to them in distant sections of the raceway.

The result is evident from some weights secured a few days ago. Various lots of York Pond fish weighed from eight to fourteen ounces to the hundred. One lot weighed one and one-half pounds, but these were selected fish from which the culls had been removed. A lot of one hundred commercial fish weighed two and one-half pounds and a second lot of these same fish weighed slightly more. Probably a selected lot could have been secured which would have weighed three or more pounds. Needless to add, we shall cross selects of the two strains, hold them under our semi-wild conditions, and hope to obtain an egg of our present high quality which will produce a fish capable of utilizing packing-house by-products for maximum growth.

Spawning fish are held in races which are ideal spawning beds. In spite of frequent handling, some eggs are deposited naturally. The seepage water has a temperature of 46°. This will cause hatching in about seventy days. Allow forty for the sac stage and the fish must be ready for food from late January to early March. Indications over a period of years are that they do not leave the gravel, presumably do not take food, until the water flowing over the beds reaches a favorable temperature. This may be at any time from the middle of April to the middle of May. Once out of the gravel, though some remain, many begin a downstream migration. These are found in brood ponds below as vigorous fingerlings when the brood fish are removed the following season. Many more, doubtless, pass out to stock the brook which drains the basin.

At the White Sulphur meeting, 25 years ago, Mr. Charles G. Atkins presented a paper describing starving experiments. His conclusion was that fry can go long without food and then feed and grow in a normal manner. Fish artificially hatched in water above 40° take food immediately the sac is absorbed. Hatched in water near the freezing point, they do not leave the bottom for weeks after the sac appears to be gone, coming up only as the temperature of the water rises.

May we not conclude that nature has thus provided against backward seasons, when the food supply may be more or less delayed.

I may add that Commissioner Brown at my request secured by

telegram the weights of three lots of fish—some of our eggs, some commercial eggs and some eggs taken at the Bennington hatchery—and the results of that telegram showed the same comparative weights as are given in the paper.

Discussion

PRESIDENT RODD: Commissioner Brown, have you some information to add to what has already been given?

MR. BROWN (Vermont): The weight of 100 York Pond fingerlings this morning was two pounds and thirteen ounces. A similar 100 fish from a commercial hatchery weighed five pounds, one ounce, and our hatchery brood stock, 100 fingerlings, four pounds, twelve and one-quarter ounces.

MR. DINSMORE: The York Pond fingerlings and our hatchery fingerlings were all eggs taken at approximately the same date; the commercial eggs were taken about a month earlier. The loss on the York Pond eggs was practically nothing. The loss on our brood stock was very small; our commercial egg loss was quite large.

MR. HAYFORD: Have you any records of the loss of fry after the feeding stage?

MR. DINSMORE: We have records, but I haven't them with me. The losses have been purely nominal; we have had no unusual loss this summer. The loss on the commercial fish after they began to feed was no greater than ours; it would fluctuate during the season. On 25,000 fish that we held in three sections of a short raceway there was a maximum loss throughout the last month of thirty-five a day, dropping frequently to one or two fish per day.

MR. HAYFORD: Our experience has been that the wild eggs give us a far better hatch, but from the fry stage on, we have much better success with the ones we have raised and held in the ponds under the same conditions as those under which we are going to rear them.

MR. DINSMORE: We have gained tremendously in three or four generations by selection.

MR. ATKINSON: While I am in favor of domestic eggs on account of the more rapid growth one can obtain in the fish, I have just been having an argument on the very point Mr. Dinsmore brought up. He said that fish from the domestic stock in the ponds took their food much more readily than the fish from wild stock. I agree—I had the same experience this year. But I feel we should consider what is going to happen to these fish when they are planted, in relation to avoiding natural enemies, whether they are not more likely to fall prey to ther natural enemies in the streams and lakes in which they are planted.

THE PROPAGATION OF TROUT IN THE KAMLOOPS DISTRICT, BRITISH COLUMBIA

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The Kamloops district situated in the "dry-belt" of British Columbia is an important center for sport-fishing. It is the type locality of the rainbow trout described by Jordan in 1892 as *Salmo kamloops*. Mindful of the increasing economic importance of this trout in that district, the Dominion Department of Fisheries and the Biological Board of Canada have undertaken to draw up a practical program of conservation for the species. Such a program can be accomplished only by observing certain requirements, namely, those of restoration and regulation. Restoration depends on successful propagation and sound regulations require an accurate and complete knowledge of life-history.

Artificial propagation is essential in certain "dry-belt" spawning streams where the watercourse may go dry in summer or where, at times, all of the water may be withdrawn for irrigation. It is also being called upon to increase the production of trout where there is a heavy fishing drain such as in the Kamloops district. In departing from natural conditions it is a complex problem to determine just how many young trout should be planted in a lake in order not to overtax its nutritive capacity and yet to farm it to its fullest extent. The method of attacking this problem forms the subject matter of the present paper.

Survey of the Kamloops Lakes

The lakes of the Kamloops district provide a typical example of the exploitation of a fishery. Since the success of fishing is so closely associated with the accessibility of the fishing ground, the waters of the Kamloops district may be divided, according to the quality of the fishing, into four main categories on the basis of accessibility, namely:

1. *Immediately accessible waters*—The waters adjacent to the old travel routes fall in this group. Many of these have been intensively fished by Indians for countless generations and by white men since Fort Kamloops was established in 1812. Kamloops lake, the North and South Thompson rivers and adjacent tributaries are typical examples of waters which are immediately accessible. The pioneers tell of daily catches of eighty to a hundred trout to be made within a few miles of Kamloops. Today this fishing has vanished. The disappearance of the trout may be entirely due to overfishing or it

may be linked with other factors, such as the disappearance of the great salmon runs. To restore the trout fishing alone might prove a highly complex problem and hence, a costly one.

2. *Waters of motor-road accessibility*—This group consists of bodies of water reached by a highway or a secondary road, and an angler may, within a short space of time, arrive at the fishing area by automobile. Lakes like Paul, Pinantan, Knouff (barren lakes stocked by the Dominion Department of Fisheries), Shuswap, Adams, Fish, and Penask lakes are examples. Owing to the ease of accessibility, these lakes are subject to a heavy fishing drain which lately has been gradually increasing. It seems to be a general rule that after a motor road has been built to a new lake depletion begins to operate. Depletion in this type of lake may be characterized by:

1. **A decrease in the amount of the catch per person per day.**
2. **An increase in the size for age of the trout in barren lakes where there are no competitors to take up the excess food supply.**
3. **An increasing proportion of younger age groups in the catch.**
4. **A decrease in the total number of fish in the spawning run.**
5. **A greater proportion of the younger age-groups ("maiden" fish) in the spawning run.**
6. **A greater proportion of fish spawning but once.**

As a rule depletion is followed by a decreased fishing effort, thus allowing a certain natural readjustment, but in lakes where competitors are present, these may rapidly fill the niche once occupied by trout. Natural readjustment because of the time element is not desirable in some lakes where important economic interests have been developed to cater to the angling trade. Expenditures for boats, gear, guides, and living accommodations provide a considerable income to the district. To the people immediately employed at any one lake cyclical fluctuations in the fishery are exceedingly unprofitable. This class of lakes, therefore, provides an urgent problem at the present time and the main part of the discussion in this paper will deal with propagation of trout in them.

3. *Waters of pack-trail accessibility*—Many lakes of this type dot the country. As in the second class of lakes, some were originally barren and have been stocked with trout. In general fishing which is carried on in them is good. They are fished mainly by a few local residents and only occasionally by pack-train parties. Hihiume, Tranquille, Paska, Face, Pillar, Hyas, and the numerous lakes in the Clearwater drainage are examples of this class. These lakes provide areas for a highly profitable type of expansion of the fishery in the district.

4. *Inaccessible waters*—A certain number of lakes lie completely beyond the limits of present road and passable trail. These form a reserve for future development.

Selection of Paul Lake to Study Type Problems

From the foregoing survey it is apparent that the waters of the motor road accessibility class are the ones most seriously threatened with depletion at the present time. The Department of Fisheries has outlined a constructive stocking program to include five of the most important of these lakes in the district, namely, Paul, Pinantan, Knouff, Penask, and Fish lakes. Of these Paul lake has been selected for the purpose of studying the following type problems:

1. The life history of the Kamloops trout.
2. The number of fish caught by anglers.
3. The number of fish which are allowed to come to maturity under this definite fishing drain.
4. The effect on the nutritive capacity of the lake.
5. The size of the planting necessary to maintain a balance between the fishing quota, mature fish and food.

The History of the Paul Lake Trout Population

Paul lake was originally barren and contained no fish of any kind until it was stocked in 1909 with 5,000 Kamloops trout fry. The term "barren" merely refers to the absence of fish from the lake, the food supply being generally quite rich. It is now known that where the food supply is abundant Kamloops trout will grow to a large size. The record weight for Paul lake is now about nine pounds, but when this stock was transferred to a barren lake near Lumby, British Columbia, the fish reached twenty-four pounds in four years (Fisheries Inspector G. N. Gartrell).

The efficacy of barren lakes in producing large trout undoubtedly lies in an abundance of food. However, a history of these lakes shows that where the spawning grounds are good they may lose their capacity to produce large trout as the population of fish becomes established. A hatchery was built at Paul lake in 1922 and transfers of the stock were made to other barren lakes. In 1917, four pairs of spawning trout were transferred from Paul lake to Knouff lake. In 1923, Hyas, another barren lake, was seeded by means of eyed-eggs taken from the Paul lake stock. The average weights (Fish Cultural Branch records) of the trout in the spawning runs of the Hyas, Knouff, and Paul stocks in 1926 were as follows:

Hyas,	12 lb.,	3 years	after stocking
Knouff,	8 lb.,	9 "	" "
Paul,	2½ lb.,	17 "	" "

Female Kamloops trout may spawn for the first time in their third, fourth, or fifth years. Having spawned once, they may survive to spawn again. Judging from the present spawning runs at Paul lake, it would be at least 1919 or 1920 before these various age-groups could be completely built up from the original planting in

1909. Fish cultural officers observed that the maximum spawning run occurred in 1924. Since the four-year-olds predominate in the spawning run, the maximum run of 1924 was probably largely due to a heavy seeding in 1920. Apparently this maximum production seriously affected the food supply.

In 1922 there was a high mortality among the kelts, which caused considerable alarm to the anglers in the Kamloops district. These kelts evidently returned to the lake to find food so scarce that they were unable to get a sufficient amount of it to recuperate after the month's starvation during spawning. Following this there was a marked decrease in the average weight of the mature fish, i. e., four pounds in 1922 to two pounds in 1925. In 1924 the hatchery officers called attention to the large number of trout containing diseased and imperfect eggs. Thus, through a complicated chain of circumstances, as the food supply decreases the size of the trout decreases, egg-production is curtailed and a natural balance between numbers, size, and food supply is eventually reached.

Under the conditions of a long-established natural balance, such as in Penask lake, the Kamloops trout does not grow much larger than one pound. It is probable that Paul lake was rapidly approaching this level in 1924. At this time a good motor road was completed to Paul lake and the fishing effort was increased. The average weight of the fish in the spawning run changed gradually from two pounds in 1925 to four pounds in 1931. A similar phenomenon has been observed at Fish lake. This lake contains a native stock of trout and large numbers of half-pound trout were formerly caught, one and one-half pounds being the maximum. Lately the size of the fish has increased. In 1931 a trout weighing nine and one-half pounds was caught and the average weight of the spawning run was three and one-half pounds. These two lakes in the Kamloops district, namely, Paul and Fish lakes, are demonstrating the natural compensation for depletion. The trout being larger on the average and in better condition, due probably to the increased supply of available food, produce more eggs and thus, by enhancing the effective seeding, the depletion tends to be counteracted. The phenomenon is the common reaction of a species to the fishing strain.

A Comparison of Lake and Stream Growth of Fry

From the foregoing account of the available history of the trout population in Paul lake it would seem safe to assume that the food supply has undergone considerable variation according to the number of trout in the lake. The richness of the lake at the present may be quite probably ascribed to the recent depletion. How can this richness be utilized without overshooting the mark? The solution seems to be rooted in the production of an effective seeding of fry and the growth and survival of the young. The most critical period seems to be that part of the early life history when the young live in

the spawning stream. After hatching, all young salmonoids spend a certain length of time in running water; the trout seem to prefer this habitat in their first year at least. Even though a seeding may be effective the preference for the stream habitat often leads to conditions of overcrowding under the most adverse circumstances from the standpoint of sustenance.

Observations made at Paul lake in 1931 tend to bear this out and emphasize the contrast between the productive capacity of lakes and streams. About three-fourths of the spawning run was handled by the Fish Cultural service and the eggs were reared in the hatchery. In July, 185,000 free-swimming fry. about one inch long, were planted around the shores of the lake. The fry which are found in the lake early in their first year (July, August, and September) constitute a group which can be identified later in life by the possession of scales with more than seven or eight rings in the first year's growth. This is the lake type.

An estimate of the number of trout in Paul creek (the only spawning stream) was made in September and found to be about 10,000 advanced fry 1.4 inches long. These fry were the result of natural seeding. They have scales bearing from one to eight rings. It is possible by means of this characteristic stream growth to recognize individuals caught in the lake which have spent their first year in stream conditions. While the sizes of the lake and stream type fry overlap to a certain extent, the averages for the two types are quite distinct.

Graph I presents the growth in inches of the two types for the first 140 days. Graph II shows the growth of the two types up to the fourth year. These curves indicate that the stream conditions retard the early growth of the trout but later the stream types grow proportionally faster and tend to catch up to the lake type. However, the important practical point is that the lake type reach the legal limit of 8 inches about a year sooner than the stream type.

The reason that growth is retarded for the stream type fry is that the food supply of Paul creek is probably insufficient for the large trout population. The part of the creek habitable for trout is about 2,000 yards long. The creek has a poor supply of food, pools are infrequent, small and shallow and the average width is about six feet. According to Embody's calculations* this stream would accommodate (biogenic capacity) about 3,000 fry, one inch long. Yet in September the creek contained 10,000 fry, one and four-tenths inches long. The fry are stunted and the growth rate is probably below normal.

The biogenic capacity of a lake has never been determined, but assuming Paul lake to be equally as productive as the best type of stream and that the potential feeding ground around the shore is

*Embody, G. C., 1927. An outline of stream study and the development of a stocking policy. Contributions from Aquicultural Laboratory of Cornell University.

seven miles long and thirty feet wide, the capacity is probably not less than 200,000 fry. The lake is therefore probably not overstocked with fry. Graph I shows that the growth rate of the lake type is high; it might even be above normal.

Advantages of fry planting—In lakes where the only fish present are Kamloops trout (a pure culture) and the stock is intended primarily for fishing or fish cultural operations, it would seem better to plant fry directly in the lake and take advantage of the rapid growth of the first year. In a pure culture the young trout are usually safeguarded from attacks by the older fish because of the stratification of the population in the lake at the time of planting. By stratification is meant the fact that the older fish seek colder, deeper water before the time when the fry are released. Very few young trout have been found in the stomachs of other trout at Paul lake.

Besides the effect on the rate of growth, fry plantings in the lake also bear a definite relation to the number of trout in a given year-group which survive. The stream will produce just enough food to maintain a relatively small number of the fish which hatch under natural conditions. A certain number of a brood may be forced into the lake, while others must certainly perish under the stress of the competition for a limited food supply, especially since in midsummer the dry-belt streams are gradually diminishing in volume as the fry tend to grow larger.

Observations on the food of young trout indicate that:

1. **The stream type fry have a diet small in quantity, restricted to insects.**
2. **The lake type fry have a proportionally larger diet (by volume), more varied in its constituents.**

The lake not only affords a greater abundance of food organisms but the variety of the diet may also provide a natural advantage for growth. By planting fry in the lake the "bottle-neck" limitations of the stream are circumvented and a greater proportion of the planting is given a chance to survive.

The rationale, then, behind fry plantings in the lake merely consists in avoiding this "bottle-neck" with two definite results: (1) an increased growth rate; (2) an increased survival value. With the increased growth rate a greater number of the young trout reach the legal limit of eight inches in the second summer, a year sooner than under natural conditions.

While depletion tends to increase the proportion of the younger age groups in the catch, intensive propagation thus speeds up production to meet the situation. The increased survival value, on the other hand, does not deal necessarily with proportions, but actually makes a greater number of "fishable" trout available.

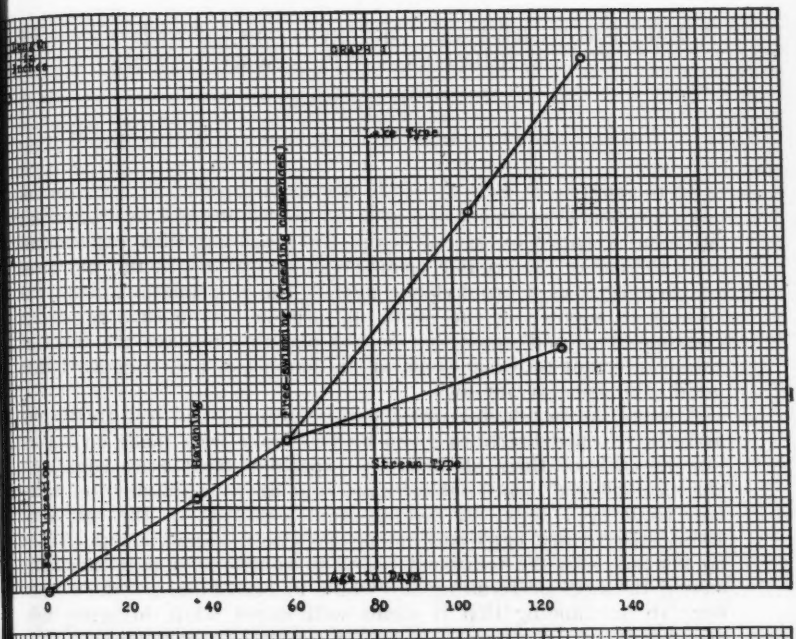
On the basis of Embody's calculations the plantings of trout in Paul lake have been set at 200,000 fry, annually, for the purposes of experiment. This number could be obtained from 125 pairs of Kamloops trout averaging about 2 pounds in weight. Under such conditions it is not absolutely necessary that more than 250 fish survive to be spawned once in order to make the trout population self-sustaining. The program seems to leave a wide margin for natural mortality and the fishing drain. In case of a surplus breeding stock there is a third benefit to accrue from this stocking rationale: the eggs over and above those required to produce 200,000 fry may be utilized to re-stock depleted areas.

Future Procedure

In an effort to establish some concrete program of operation for meeting the complex situations arising in the Kamloops district and to derive a fish cultural formula for stocking purposes an attack will be made on the problem by following the life history of several generations of trout with:

1. **Definite annual plantings of fry in the various lakes controlled by the fish cultural program (Paul, Knouff, Pinantan, Penask, and Fish).**
2. **Determinations of the yield in Paul lake by an enumeration of the fish in the fishing quota and the spawning run.**
3. **An annual determination of growth rates in the five lakes for signs of fluctuation in size for age.**
4. **Studies on the food types for correlative fluctuations.**
5. **A complete "check-up" of the productive capacity of the lakes at definite intervals.**

After a certain time has elapsed, if the annual planting of 200,000 fry in Paul lake is followed by an increase or decrease in the food supply, the number can be modified and eventually a balance between the various contributing factors may be realized. Thus it may be possible to gain knowledge for applying measures of conservation to the other bodies of water and to farm our public fishing waters in order to smooth out uneconomic fluctuations.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Late Type
Average
Size showing Quarterly Progression
Stream Type
Age in Days
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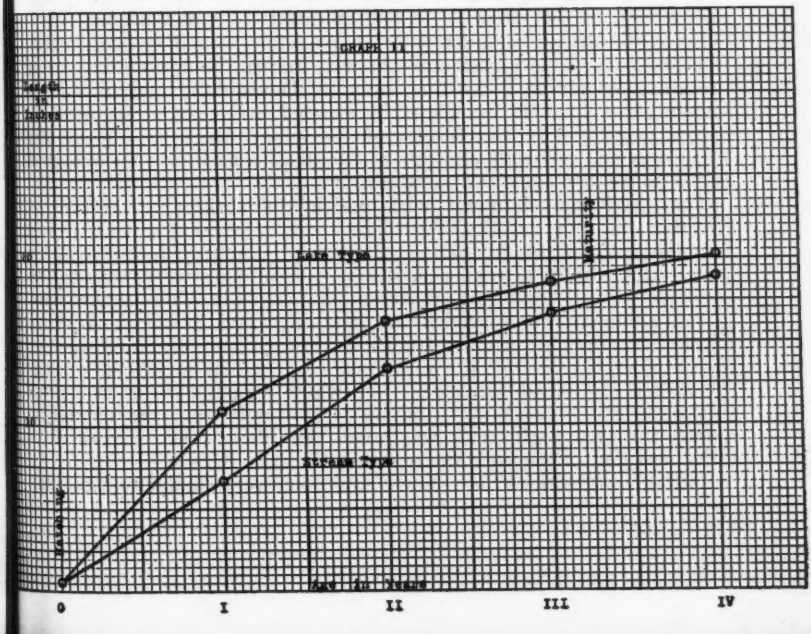
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Late Type
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IV

A BACTERIAL DISEASE OF TROUT EGGS AND FRY AND ITS PROPHYLAXIS WITH ACRIFLAVINE

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In the autumn of 1931 Mr. J. A. Rodd, Director of Fish Culture of the Canadian Department of Fisheries, kindly brought to the writer's attention a paper by Isobel Blake ('31) dealing with experiments with the use of the organic disinfectant, acriflavine, in the treatment of trout eggs as a prophylactic against the transmission, from one locality to another, of the germs of furunculosis on such eggs. At the time Mr. Rodd stated that he was planning to have the effect of the disinfectant tested at some of his hatcheries and suggested that we do the same at our own.

A supply of acriflavine was therefore secured and test treatments according to the directions given by Dr. Blake were made on a portion of each of three shipments of speckled trout eyed eggs, one shipment of land-locked salmon eyed eggs and one shipment of rainbow trout eyed eggs. A careful count was kept of the mortality among the treated eggs and among the control experiments and in no instance was the treatment found to cause any undue mortality among the eggs or resulting fry while, in one shipment, the results were so outstanding that it seems well worth while bringing this disinfectant to the attention of fish culturists on this continent.

Since the disease against which acriflavine proved such an effective prophylactic is apparently not well known, being referred to in literature, so far as I can find, only by Davis ('29) and in a little known paper by Von Betegh ('12) which Davis cites, it seems well, before dealing with the results of the experiments, to outline the symptoms and probable etiology of the disease as it was encountered in the untreated eggs and resultant fry.

The particular shipment with which the acriflavine proved so effective was one of 200,000 speckled trout eyed eggs from three-year-old selected stock from a commercial hatchery in the eastern states which holds a good reputation. These eggs were received in apparently good condition on December 9th, 1931. The major part of this shipment was placed in the hatching trays in normal fashion without treatment. Almost from the time of arrival there was an undue mortality among the untreated eggs which increased during the rather prolonged hatching. The water temperature at this time was generally between 32° and 34°. Not only was the mortality among the eggs high but it was noted that about 30% of this mortality was due to the yolk sac bursting through the shell.

As the fry developed they showed symptoms very similar to those de-

scribed by Von Betegh (*loc. cit.*) for a disease to which he gave the name *Hydrocoele embryonalis,* considering it probably to be caused by a bacillus which he named *Diplobacillus liquefasciens piscium.* Superficially the symptoms rather resemble blue-sac, the yolk sac becoming much distended with a nearly colorless liquid and the fish eventually dying, although, at the temperature prevailing with us, sick fry often lived several weeks. One symptom which Von Betegh did not mention for the epidemic he observed but which was general with us was a distinct blood clot on the yolk sac. The disease may apparently be transmitted from infected fry to healthy fry as well as to eyed eggs. Eventually all of the shipment, except that portion treated with acriflavine, was lost.

Through the courtesy of the Central Experimental Farm at Ottawa cultures were made by Dr. Lochhead, bacteriologist there, from the infected fish and several strains of a diplobacillus were isolated in pure culture. This organism closely approximated the description given by Von Betegh. Attempts this spring to re-infect rainbow eggs from these cultures, while suggestive, were not conclusive, possibly owing to the more rapid development of this species. It is hoped to carry out re-infection experiments this winter with speckled trout so as to establish definitely the causative organism of this disease.

For the acriflavine test a roughly measured three thousand eggs were treated for twenty-five minutes with a 1/2,000 solution as directed by Dr. Blake. The first thing noted was that the mortality was lower with very little bursting of the yolk sac, the second that the hatching was delayed as compared with the untreated eggs, being completed on February 24th, eleven days later than these. Since no delay in hatching was observed with other shipments, it appears that the apparent delay was, in reality, merely the prevention of a premature hatch caused by the distension of the yolk sacs of infected fish.

The total observed mortality of eggs and fry from the treated 3,000 was, up to July 31st, 974, half of this occurring by the end of March. That the figure is rather high is, no doubt, largely due to the eggs being shipped some distance and from water at 45° to 50° to water at 32° to 34°. On the same date 2,038 healthy fingerlings were counted, or a fingerling survival of approximately 68%.

The experience related above therefore shows that acriflavine, in addition to being a prophylactic against the introduction of furunculosis on fish eggs as Dr. Blake demonstrated, is equally effective in this function against a diplobacillus, probably *D. liquefasciens piscium.* It is our intention in the future to disinfect any eggs received from outside points, since the cost of the disinfectant is negligible compared with the loss, the cost of sufficient concentrated solution of acriflavine to make two gallons of 1/2,000 solution, which will treat 100,000 eggs, being about three and one half dollars in Canada.

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Discussion

MR. ADAMS (New York): Will Mr. Atkinson explain just how that treatment was applied?

MR. ATKINSON: The eggs were covered with the solution and slightly agitated at intervals over a period of twenty-five minutes or so, to make sure that there was complete contact.

MR. ADAMS: How were the eggs agitated?

MR. ATKINSON: Just by a slight stirring with a feather.

MR. ADAMS: How often during the period—continuously, or at intervals?

MR. ATKINSON: About every five minutes.

MR. ROWE (Maine): I gather from your paper that the treatment was carried on at different periods. Did one shipment go by without treatment, and then a later shipment came in and you made the test? In other words, with eggs which arrived at the same time, with the same shipment, did you have it both ways—treated and untreated?

MR. ATKINSON: Last winter I received five different shipments of eggs, because I was trying to decide which would be most satisfactory; and in each instance I treated a portion of the shipment and left one portion untreated. I think, therefore, my control is accurate. When you lose 195,000 and save 2,000 and more out of the 3,000 you treat, I think you have established a fact. In that same connection I may say that in a different shipment of eggs I have taken a much higher survival of fingerlings. From a shipment of 25,000 eggs from a commercial hatchery I counted at the end of last month 23,568 fingerlings; so that the survival I gave was in any event somewhat low.

DR. EMMELINE MOORE: What is the source of supply of this disinfectant? Is acriflavine a commercial product?

MR. ATKINSON: I imagine that you could secure it from any large wholesale druggist. Mr. Rodd had no difficulty in obtaining it. In this particular

work I followed the President's advice and procured the solution in concentrated form ready for dilution, rather than in the dry state.

MR. HAWLEY (New York): For Dr. Moore's information I may say that the Carbic Chemical Company of New York are the sole handlers of acriflavine. They will supply it without charge for research purposes.

PRESIDENT RODD: I have no difficulty in getting acriflavine from the wholesale druggists.

PROBLEMS OF PONDFISH CULTURE

T. H. LANGLOIS

Chief, Bureau of Fish Propagation, Ohio Division of Conservation

The methods used for the propagation of bass vary so much that a classification of them may add to the clarity of my description of the Ohio system.

Bass may be propagated under natural conditions in large ponds ranging from two to fifty acres in area, wherein the bass are the single climax species and the natural food cycle leading up to it prevails. In such ponds the brood stock is maintained at all times. The annual crop of fingerlings is removed by seines or traps or by drainage of the pond. Bass may also be propagated under semi-natural conditions in smaller ponds of from one to ten acres in area into which the young bass are placed or in which the breeders may spawn and remain with the young throughout the season. The natural food supply in these ponds may be supplemented by the periodic additions of forage fish.

In contrast to the procedures just described, bass may be reared under conditions that may be called artificial. Breeders may be placed on special ponds where conditions favorable for their spawning are provided, and the fry are removed soon after hatching. The fry may be planted at once, or they may be placed in separate ponds, or raceways, or troughs, for rearing. The rearing ponds may contain still or running water, and they may or may not have been prepared in advance for them by the use of fertilizers and the production of entomostracans. The young bass may thereafter be fed only on entomostracans cultured elsewhere, or upon Daphnids first, then forage fish, or they may be hand fed some artificial food such as ground fish or clam meats, or other acceptable food.

The system of state-owned pond-fish hatcheries in Ohio consists this year of 109 ponds with a total water area of fifty-two acres. These ponds range in size from about one-third to three-fourths of an acre in area, and the attainment of quantitative production can only be accomplished by intensive use of these small areas. This establishes at once the fact that artificial conditions must prevail, and the chief feature of this departure from the natural consists in the reduced water volume per fish, or the crowding together of many individuals in limited space. It is futile to expect such numbers of fish to thrive upon the normal food cycle that prevails in our northern waters, and it is obvious that other food must be made available.

The tendency of spawning bass to molest each other results under natural conditions in the wide separation of nests. In our hatchery

breeding ponds we place as many adult bass in a quarter acre pond as would occur naturally in a pond of two acres, and to enable them to spawn without mutual interference we have built gravel-bottomed stalls around the pond margins. Then, whereas under natural conditions the parent bass would school his young for a time after they leave their beds, we relieve him of this duty, and transfer the young to ponds where they are safe from the bigger fish.

All of the food which young bass consume during this first year in the hatchery pond is utilized for activity and growth, and the growth attained is a direct indication of the ampleness of the food supply. Moreover, bass, particularly the largemouthed bass, are fish eaters, and it is essential that an ample supply of food should be constantly available or there will be some which get food and some which do not. Those which get food grow, and those which do not get food do not grow, and when some of the bass discover that there are smaller fish present the survival ratio goes down.

In the Ohio hatcheries we are attempting to solve this problem of feeding young bass by the use of *Daphnia magna* and ground frozen fish. We have some small Daphnia culture ponds, and the Cladocerans produced in them are used to inoculate the rearing ponds. By transferring many water fleas to the rearing ponds last fall just before the winter freeze-up the foundation was laid for a heavy production of them the ensuing spring. The ponds where this was done were brown with *Daphnia magna* when the bass fry were introduced about May 15, and the young bass grew rapidly. During the first two weeks in June the bass commenced feeding on ground frozen fish, and they have been fed nothing else since.

In 1931 there were 51,000 pounds of ground fish used as bass food, and by September first, 1932, our bass had consumed over 100,000 pounds. At the Hot Springs meeting of this Society last year Mr. Dell Brown and Mr. Joe Hogan estimated that they were using about four ponds for the production of forage fish to each pond containing bass, and that even at this ratio their bass were underfed from July through the balance of the season. Obviously, it would be unsound economics and impractical for Ohio to attempt to produce sufficient forage fish to adequately feed our bass throughout the entire season.

In 1932 the practice of using fresh fish to start the young bass taking artificial food was discontinued and frozen goldfish were fed from the start at several hatcheries. At four others the bass were fed carp which had been removed from Lake St. Marys, an artificial lake of 17,000 acres built as a canal reservoir nearly a hundred years ago. The Ohio Division of Conservaton has begun this year an attempt to make this lake again a game-fish lake by encouragement of vegetation and removal of the carp, and a large share of the expense of the carp removal is saved by making this use of the carp. The goldfish cost us one cent per pound this year, and the seine fisher-

men are very glad to find this market for an otherwise unsalable fish. For three of the hatcheries we purchased shopworn lake herring and it must be a good thing for the Great Lakes fisheries to have had the 32,000 pounds we used taken off the market for human consumption.

The accompanying table presents some data on the food requirements of bass, based upon calculations of the season's total of the pounds of ground fish fed to the young bass in those ponds which contained no other fish but bass. In other ponds the records would not apply to this report because of the combination of bass with other species or because the season's record was not continuous for some reason or other. The records to be cited are for those ponds which contain only bass and the bass contained therein were fed only ground fish for the entire season. It is recognized that these figures take no account of waste, nor of whatever natural food the fish may have obtaned, including, of course, some of their own kind.

30 ponds. 13.58 acres.
115,990 fingerlings weighing 5,658½ lbs.

Average weight	**.78 ounces**
Average length	**4.33 inches**
Total food fed	**28,526 pounds**
Average pounds food per pound bass	**4.16**
Average ounces food per fish	**8.54**
Average number fingerlings per acre	**3.93 ounces**
Average pounds bass fingerlings per acre	**5.04 pounds**

The Ohio system of feeding bass is more satisfactory for smallmouth than for largemouth or spotted bass. The smallmouth bass take to feeding on the ground fish sometimes between their second and fourth week, and our procedure from then on is to feed them all of the food they will take. Inequality of growth is an index of improper or inadequate feeding, and when it becomes apparent, it becomes absolutely essential to feed constantly and copiously. If this is done, all sizes will feed together freely; but any interruption at this time will change the big ones into cannibals almost over night.

With largemouthed bass it is different, for their big mouths seem to accompany a predaceous disposition. They invariably grow unequally in all of our ponds, regardless of feeding efforts, and, although all sizes take the food very readily, they do not feed together. The big ones occupy the deeped waters of the pond, while the little ones swim around the edges. We have tried draining ponds in midsummer and sorting the largemouth fingerlings according to size, but this procedure accomplishes little good, for in a short while a few of the uniformly little ones will have outgrown their fellows and will have become cannibals like the first crop of bullies. The solution appears to be the use of long, narrow raceways where the fish are under constant observation and are easily available. Under these

conditions they may be sorted frequently as to size and segregated into size groups.

At the St. Marys hatchery five ponds ranging from five-tenths to seven-tenths of an acre in area became clogged with *Potamogeton Natans,* and one other of three-tenths acre had great quantities of one of the slender leaved type of Potamogeton. Largemouthed bass are reared in these ponds, and the presence of this vegetation seriously interfered with the feeding of the bass. Our experiments last year with the use of sodium arsenite led us to extend its use in 1932, and these ponds were all treated with four pound weed-killer. The stems of the plants turned brown and broke off just above the pond bottom, and the mass of vegetation floated at the surface. This was pushed into windrows and removed to prevent its decomposition within the ponds and the vegetation has not come back in the ponds this season. The water in these treated ponds became brown and of low transparency following the use of sodium arsenite, and the advantage gained for feeding by removal of the vegetation was partially offset by the disadvantage of turbid water.

The procedure started in 1931 of rearing young goldfish to place in the ponds with the bass breeders in the fall for winter feeding brought the breeders through the winter in good condition and has been repeated this year. During the 1932 spawning season our 1,782 breeder bass produced 1,126,635 fry.

The ponds at the Xenia hatchery derive their water supply from springs in their bottoms and the flow through them is not great. Four of them were used for wintering the breeder bass because of their depth of eleven feet, and because they are so cool they hold the breeding season back in the spring. In April when we were getting ready to transfer the breeders to the shallow breeding pond we discovered that they were covered with white spots and were heavily infected with Ichthy ophthirius. There is no record of previous infection with this parasite in this hatchery, and the source of the infection is not known, but the young goldfish that were placed in the pond as food for the breeders are under suspicion.

The interesting thing about this white-spot infection is that it disappeared almost of its own accord. When the breeders had been removed the ponds were refilled at once, and in a few weeks bass fry were placed in them. The young bass have done exceedingly well, and there has been no evidence of white spot on any of them. One of the older hatchery superintendents informs me that he has seen breeder bass come clean out of similar white-spot epidemics on other occasions, and that the largemouth bass do not seem to be infected by this parasite as severely as the smallmouth bass. Although two of the four ponds contained largemouth and two ponds contained smallmouth, and the opportunities for transmitting the infection were great, the largemouth bass in this case also remained entirely clean.

In the ponds which were occupied by breeder bass last winter, there are no crayfish this summer, but in the other two ponds crayfish abound. Using the feeding methods we do, namely, casting fresh ground fish to the bass, there is of necessity some waste that goes to the bottom. This is ideal food for the crayfish, and they have become very abundant in these two ponds. All six of these ponds were fertilized with sheep-manure and superphosphate last spring and were brown with *Daphnia magna* on May 15th, when smallmouth bass fry were introduced. The fry grew rapidly and were quite uniform in all six ponds on May 27th, when the crayfish roiled those two ponds up. With the loss of transparency the entomostracan very quickly disappeared, and the fish suddenly started taking artificial food. In the other four ponds, the bass continued feeding on entomostracans and it was two weeks later before they started feeding on the ground fish. This two weeks' lead had given the fish in these two ponds a big advantage, and they have outgrown the bass in the other four ponds.

Another observation bearing on the same point was made at the Piqua hatchery. The breeder smallmouth bass were removed when they finished spawning from the pond containing spawning stalls, to another pond, and the breeder pond was stocked with largemouth fry. The screens were slipped in the spawning stalls and they were fertilized and inoculated with *Daphnia magna*. The screens were sixteen mesh, coarse enough to hold the adult Daphnias in and let the young ones out. In a short while many of the young bass had become accustomed to feeding on the young entomostracans and a row of them was to be seen lined up with their noses to the screen, grabbing all that came through. The fish in the other end of the same pond learned to take artificial food, and at the end of about six weeks there were two obvious size groups in the pond. The fish taking ground fish averaged at least an inch longer than the ones feeding on entomostracans, and to avoid cannibalism, the screens were withdrawn and the cultures were cleaned out.

It seems then that, although it is essential to make Daphnia cultures in the rearing ponds and to maintain them while the bass are very young, there comes a time when the bass do not make the maximum possible growth on an exclusive diet of this nature. It appears further that, if the entomostracans can be eliminated suddenly from the fish pond at this stage of development, the bass will all readily form the habit of taking artificial food. The use of kerosene to accomplish this elimination of entomostracans appears to be preferable to the use of crayfish because it does not leave the water roily for the balance of the season.

Autumn has made manifest its approach in Ohio since the first of September by cool nights, and the fish ponds have had their surfaces chilled nightly by this change. Only about the upper six

inches of water have been affected, and the smallmouthed bass have responded by swimming in the warmer water below.

The days have been clear and warm, but the surface waters have not attained the warmth of the water just below until mid-afternoon. The smallmouthed bass fingerlings have adjusted their feeding to this schedule, refusing to rise through the cold upper layers to feed, and feeding only from about 3:00 to 5:00 P. M., after the surface waters have become warm. The total amount of food consumed by the smallmouthed bass dropped almost to one-half with this change of schedule, but the largemouthed bass have been almost unaffected; many ponds of the latter species actually having consumed more each day in accordance with the demands of their regular increase in size.

The adult bass in our breeder ponds appear to undergo feeding cycles that offer material for speculation. The quantity consumed rises steadily during the breeding season to a peak at its termination, about June 12. From this peak it drops, then rises again to another peak about July 20, then falls and rises again about the end of August. There is no apparent correlation of these feeding cycles with the phases of the moon or with temperature cycles.

On Page 112 of the 1931 Transactions of the Society, the author of this paper described the type of spawning stalls which had proved very successful in smallmouth bass breeder ponds. This first set of forty stalls was built in 1930 at the London hatchery, and in 1931 the system was extended by the construction of eighty-five at Newtown, forty at Xenia, thirty at Piqua, eighty-five at Bucyrus. The first ones, at London, were built in the middle of the pond in a double row, opening both ways, but all of the new ones were built in series around the pond margins. The use of these stalls has made it possible for us to obtain some very accurate information on the spawning of smallmouth bass. Each stall is numbered and the fry were hand-counted out of each stall separately.

The spawning pond at the Xenia hatchery is small and rectangular, with dimensions of 40 by 80 feet, and depths ranging from a uniform eighteen inches around three shores to three feet along the fourth side and at the drain. The three shallow sides have been occupied by spawning stalls, ten in a row along the two forty-foot ends and twenty in a row along the one eighty-foot side. Each stall is four feet wide across its front and reaches out into the pond five feet. Along the front of this row at the upper edge of the stalls there is a 1 by 6 inch board, and when the pond is filled the surface of the water reaches about half way up this board. This prevents the waves from disturbing the surface of the water in the stall and provides clear visibility at all times. Screen slots have been built directly behind this board so that when the proper time comes the box can be screened off from the balance of the pond. River gravel was placed in the bottoms of these stalls, and the balance of the

pond bottom is surfaced with mud. One hundred and twenty adult smallmouth bass were placed in this pond on May first, 1932, and the following table of data about their spawning contains records made by Ernest Harner, Superintendent of the Xenia hatchery.

In addition to the sixty-six bass beds for which the data are given there were fourteen others which failed to yield fry, making a total of eighty beds from 120 breeders. Of the eighty beds, all but fourteen were made within the stalls, and the fry from the ten good beds out in the pond were mostly obtained by siphoning over the levee into tubs below. The loss of the fourteen beds was caused by refanning, none of the eggs simply going bad. All of the beds apparently yielded a high percentage hatch, and the small number of fry obtained from some of them, together with the large number of beds for the number of breeders, leads to the suspicion that some of the females may have spawned in more than one bed.

On one nest, Mr. Harner observed the same male spawning with two females within an hour or two. Another male had a blind eye which identified him, and he incubated and hatched two beds of eggs in succession. He was shut off from his first bed one evening when they were hatching, and he appeared on an entirely new bed of eggs in another stall across the pond the very next morning. Unfortunately we do not know the sex ratio of these 120 breeders. Every one of the forty stalls was spawned in at some time during the season, one of them four times, but at no one time were they all occupied. As soon as the eggs were deposited in stall 40 on June tenth, the screen was slipped in place, and this bed yielded 5,207 fry in seven days, the same incubation period for other beds made the same day, entirely without parental attention. The water in this pond comes from another pond and is entirely devoid of silt, and it seems probable that under these conditions the fanning of the male is not necessary.

The correlation of spawning of the smallmouth bass with temperature is evident from the table of data. It will be noted that the spawning occurs on a rise in temperature, and that nearly every rise in temperature was accompanied by the breeding of a number of bass. It will be noted further that the incubation period ranged from sixteen to seven days, and that the first eggs of any batch of beds, which were deposited at the beginning of the rise in temperature, required a day longer to hatch than the ones deposited in warmer water. Clear weather prevailed from the beginning to the end of the spawning season except for the following days which were cloudy: May 1st, 10th, 11th, 12th, 13th, 28th, and June 12.

Among the obstacles encountered in 1932 may be listed the very serious problem of predaceous insects. In three ponds at the London hatchery the backswimmers, *Notonecta undulata* Say, were so numerous that two overcasts from a single place along shore with a 4 by 8 foot minnow seine yielded about 300 adults and nymphs.

Stall No.	Date Eggs Were Deposited	Date of Hatching	Days of Incubation	No. of Fry	Date	WATER Min. Max.	AIR Min. Max.
5	May 3	May 15	12	4,624	May 1	62 — 64	44 — 67
8	3	15	12	1,857	2	60 — 66	35 — 59
	3	15	12	4,455	3	60 — 66	32 — 64
16	5	16	11	11,329	4	62 — 70	51 — 83
25	5	16	11	6,193	5	64 — 70	56 — 83
35	5	16	11	3,181	6	66 — 72	51 — 84
12	6	17	11	2,400	7	68 — 74	60 — 85
40	6	17	11	7,100	8	70 — 76	61 — 85
	7	18	11	4,200	9	68 — 76	49 — 76
1	7	18	11	860	10	68 — 70	53 — 68
	7	18	11	9,815	11	66 — 68	52 — 66
22	7	19	12	4,100	12	62 — 64	52 — 66
24	7	19	12	3,070	13	60 — 66	48 — 70
28	8	20	12	3,960	14	64 — 68	49 — 77
38	8	20	12	1,300	15	64 — 72	54 — 86
20	8	20	12	2,788	16	68 — 72	54 — 83
27	8	20	12	1,070	17	62 — 72	41 — 66
	8	20	12	4,960	18	66 — 70	37 — 64
33	8	21	13	3,000	19	62 — 72	38 — 75
23	10	23	13	4,000	20	68 — 74	48 — 80
21	10	23	13	3,200	21	68 — 76	54 — 86
20	10	23	13	4,000	22	70 — 72	47 — 76
	10	23	13	2,500	23	63 — 73	35 — 76
2	14	25	11	3,650	24	70 — 76	40 — 87
3	15	25	10	3,000	25	70 — 76	59 — 85
14	15	25	10	3,400	26	74 — 78	65 — 87
4	15	25	10	2,860	27	74 — 76	62 — 84
39	15	25	10	2,500	28	66 — 76	44 — 76
15	15	25	10	3,200	29	60 — 68	34 — 70
	15	25	10	3,500	30	64 — 70	40 — 78
	15	25	10	3,000	31	70 — 72	44 — 80
	15	25	10	3,250	June 1	70 — 72	61 — 78
37	17	June 1	14	1,090	2	70 — 74	61 — 83
3	17	1	14	3,032	3	72 — 74	56 — 86
8	18	3	16	928	4	74 — 78	60 — 88
	18	3	16	1,300	5	76 — 80	61 — 89
22	18	3	16	8,260	6	76 — 80	62 — 88
32	18	3	16	1,850	7	76 — 78	61 — 87
1	18	3	16	3,800	8	72 — 74	45 — 79

Stall No.	Date Eggs Were Deposited	Date of Hatching	Days of Incubation	No. of Fry	Date	WATER Min. Max.	AIR Min. Max.
40	May 30	June 7	8	950	June 9	72 — 76	42 — 79
9	30	7	8	1,520	10	74 — 78	47 — 84
5	31	7	7	4,315	11	74 — 76	56 — 84
13	31	7	7	275	12	75 — 77	60 — 80
17	31	7	7	250	13	74 — 77	59 — 84
19	31	7	7	500	14	72 — 78	53 — 87
21	31	7	7	2,472	15	73 — 78	62 — 82
29	31	7	7	694	16	74 — 78	62 — 82
7	June 1	8	7	2,300	17	73 — 78	57 — 85
40	10	17	7	5,207	18	75 — 78	65 — 86
8	10	17	7	4,130	19	73 — 78	64 — 89
4	10	17	7	3,450	20	75 — 79	67 — 86
7	10	17	7	1,557			
3	10	17	7	1,176			
14	10	17	7	1,968			
16	11	18	7	3,075			
10	11	18	7	3,264			
18	11	18	7	92			
6	11	18	7	615			
22	11	18	7	3,583			
28	11	18	7	2,172			
	12	19	7	2,610			
5	12	19	7	2,245			
25	12	19	7	731			
2	12	20	8	210			
17	12	20	8	222			
1	12	20	8	9,950			
				202,105			

Largemouth bass fry were placed in these ponds and the backswimmers ate them all in a very short time. By spreading, in calm weather, five gallons of kerosene on a half acre pond a surface film was produced and the bugs were practically all killed in a very few minutes. As these insects came to the surface for air, they grew frantic when they obtained, not a bubble of air, but a coating of coal oil to carry down with them. They were all dead by the time the surface film had disappeared by flowing off and by mixture with the water. This procedure was later used on ponds containing fish, without harm to the fish. Incidentally, the kerosene also kills the whirligig beetles which abound on most fish ponds, and, to our surprise, it also caused the *Daphnia magna* to die and bunch up at the surface after about two hours.

The larvae of the Dytiscid beetles, the so-called water-tigers, also caused us trouble. At the Newtown hatchery, Pond 11 was stocked with 19,505 bass fry on June 4. On July 2, when the bass averaged one and one-half inches in length, many freshly killed ones were seen lying about the pond bottom. Their bodies were clean and fresh but their entire bellies were eaten away. The pond was drained and the survivors, reduced in number to 6,238, were moved to another pond where they have since grown marvellously. As the waters receded, the dead fish were examined, and many of their bodies covered the larvae of the Dytiscid beetle. One of the hatchery men witnessed an actual attack, and related that the larva lay on top of the vegetation and that, as the young bass was passing over, the larva executed a few quick body-flips and with his pinchers grabbed the bass by the belly wall. Besides finding the water tigers beneath the fish bodies, we found in a similar position one dragon-fly naiad, identified by Dr. H. H. Hungerford of Kansas as belonging to the genus *Coryphaeschna.*

Ohio propagates and distributes the marbled catfish, *Ameiurus nebulosus*, and one feature of our procedure may be worth mentioning. The catfish are fed a mixture of middlings and meat scrap, and this year, instead of broadcasting the food all over the shoals, it has been placed in V-type feeding troughs. These troughs are placed at right angles to the shore-line, sloping down into the water, and the deeper end is propped up off of the bottom to within a foot of the surface of the water. The young catfish swarm into the troughs within a few minutes after the food has been placed in them, and clean troughs indicate the possible need for additional food, while any excess is easily apparent.

To protect the levees in ponds containing breeder catfish from the nesting burrows eight inch field tile are placed in a horizontal position with one end embedded in the sloping bank within about a foot of the surface of the water, and the catfish nest within them. Each year there are many beds made about May 15th, and the schools of fry appear three or four weeks later. During the month of August

there are many schools of newly hatched fry that apparently come from beds down deep in the ponds, for no beds have been seen in the tile near the surface. Whether some of the breeders spawn twice in a season or spawn only once late in the season remains to be determined. This procedure has the result of making the ponds where it occurs yield two size groups, and the late-hatched smaller group reduces the average size of the fish when they are distributed. The same facts apply to bluegills. There are always some bluegill beds in August, and no matter how large the fish hatched in May may get to be, the fry that come out in August keep down the average size of the fish taken out of the ponds.

Discussion

MR. CULLER (Wisconsin): What was the average production per acre in numbers of fish, not in pounds?

MR. LANGLOIS: 8,541.

MR. MARKUS (New York): In feeding these bass the ground fish food I understand you just throw it into the water and the bass take it. Did any of the food go to the bottom?

MR. LANGLOIS: Very little; the bass nip at it as it reaches the surface.

MR. MARKUS: Do the bass pick it up off the bottom?

MR. LANGLOIS: I do not think they do to any appreciable extent. I think the food they get is what they get as it hits the water.

MR. ADAMS: I would like to ask Mr. Snyder, of the United States Bureau of Fisheries Station at Cape Vincent, if in his experiments in feeding dried shrimp meal to smallmouth bass in aquaria they would pick fragments off the bottom that they did not catch as they were dropping down through. I have a recollection I saw them doing it.

MR. SNYDER (New York): Yes, sir, they did. When we began feeding our fish in the ponds they tended to run away from it before they learned to take the food; but by standing still we noted that they came back and would go down and pick that food right off the bottom.

MR. LANGLOIS: I did not mention that this proposition of feeding the bass is largely a matter of getting the food to them. It is the tendency of the bass to swim out to the middle of a deep pond where there is much vegetation, and that is why we are shifting over to the long narrow raceway. Instead of using a square screen in front of the overflow from one pond to another, we are using now a triangular screen, which we like very much. We can keep the screen clean at all times, and it provides a larger screen area so that the water flows through the overflow more freely.

For our transportation we use eight tanks placed sideways on the truck.

MR. ADAMS: What are the dimensions of the tanks?

MR. LANGLOIS: Two by two by forty-four.

MR. ADAMS: Do you supply any oxygen to them?

MR. LANGLOIS: No; moving our hatchery fish only in the fall we have not found it necessary.

ECONOMIC BASS CULTURE IN TROUT WINTERING PONDS AT THE HACKETTSTOWN STATE FISH HATCHERY

CHARLES O. HAYFORD

Superintendent of Fisheries, Hackettstown, New Jersey

For many years we have been experimenting on how to produce the greatest number of bass per acre. The best method we have discovered up to the present time is the use of trout excrement, a product that for many years we have let go to waste.

We have twelve trout ponds ranging in size from one-half to a little over an acre each that we use for wintering 200,000 eight to fourteen inch trout.

In the spring of 1931 we netted the trout from pond No. 12 containing 1.27 acres, leaving all excrement and silt that had collected during the period of eight months.

After one week the pond was allowed to fill slowly until it reached normal level. All water was then shut off. Daphnia was introduced and allowed to reproduce for ten to twelve days, at which time the pond was a swarming mass of Daphnia and other aquatic life.

On June 27th we placed 20,000 largemouth bass advanced fry three-fourths of an inch long in this pond, 15,748 per acre.

From June 27th to August 3rd nothing was done to this pond except to maintain the water level. During this time the only food the bass had was the aquatic life produced in these ponds.

On August 3rd, and 4th, we netted from pond No. 12, 17,157 bass three to four inches long, an average of 13,509 per acre, a loss of 2,843, or 14.2%, at a cost of approximately $6.61 per thousand.

In 1932 on June 13, 31,200 bass fry one-half of an inch long were placed in pond No. 12, 24,566 per acre. On September 10th we netted from this pond 21,083 three-inch bass, 16,600 per acre, a loss of 10,117, or 32.4%, at a cost of approximately $4.93 per thousand.

It cost approximately $81.89 per acre for actual labor to produce these bass each year.

On June 27th, 1931, we placed 17,000 advanced largemouth bass fry three-fourths of an inch long in pond No. 8 containing .75 of an acre, an average of 22,673 per acre.

Every day at eight o'clock we permitted the Daphnia from pond No. 7 containing .47 of an acre to flow into No. 8 for thirty minutes and again at four o'clock for thirty minutes.

All the trout excrement was left in pond No. 7 and we used 1,500 pounds of horse manure every two weeks further to fertilize the pond.

The area of the Daphnia pond and bass pond, 1.22 acres, produced 14,393 bass three inches long, an average of 12,401 per acre.

Cost of operating these two ponds:

Netting fry from reservoir	$15.00
2¼ tons of horse manure	4.50
Labor and truck spreading manure	9.00
Labor flowing daphnia through pond	20.00
Netting and shipping bass	27.00
	$75.50

an average of $61.85 per acre, average cost of bass $5.25 per thousand.

On July 1st, 1932, we introduced 20,000 largemouth bass fry one inch long into pond No. 8, an average of 26,666 per acre. From August 1st, these bass were fed chopped sheep hearts twice daily.

On September 16th we netted 18,383 bass three to four inches long, an average of 24,510 per acre, a loss of 1,617, or 9.80%.

Cost of operating pond No. 8, 1932:

Netting fry from reservoir	$15.00
½ ton horse manure	1.00
Labor spreading horse manure	1.50
Labor feeding bass	23.50
Cost of sheep hearts	23.50
Netting and shipping bass	27.00
	$115.50

an average of $154.90 per acre, averaging cost of bass $6.28 per thousand.

Discussion

ALFRED M. MCGAVOCK (United States Bureau of Fisheries): The purpose of the experiment, which was carried on this summer by the U. S. Bureau of Fisheries in cooperation with the Hackettstown, N. J., State Hatchery, was to determine which of three methods of Daphnia feeding was the best and most economical in raising bass.

In pond No. 11 the Daphnia were cultured in the main pond from fresh manure. The area of the pond was .63 acres. A total of 8,010 pounds of manure was used, in addition to about two inches of trout excrement. There was an average of 18.74 grams of bottom food per square meter, and an average of 278 grams (wet weight) of plankton organisms per cubic meter of water. However, part of this plankton was volvox, which is not used as food.

On June 11th, 1932, the pond was stocked with 15,750 smallmouth bass fry, at the rate of 25,000 per acre. The pond was drained September 8th and we removed 8,156 fingerlings with an average weight of 6.48 grams and an average length to the base of the tail of 2.88 inches, and also twenty-two select fingerlings with an average weight of 17.2 grams, and an average length to base of tail of 3.95 inches. This is a return of 51.8% or 12,990 fingerling per acre.

The cost of labor was $148.50 per acre, and the cost of manure was $25.80 per acre, making a total cost of $174.30 per acre, or $13.40 per 1,000 fingerlings.

In pond No. 10 the Daphnia were cultured in a separate pond and either flowed or netted over into the main pond. The area of the pond, including the Daphnia pond, was .69 acre. A total of 8,760 pounds of manure was used, and in addition about two inches of trout excrement. There was an average of 23.5 grams of bottom food per square meter, and an average of 21.8 grams per cubic meter of plankton food in the pond. The larger Daphnia were consumed almost as soon as they were put in the pond.

On June 9th the pond was stocked with 17,250 smallmouth bass fry, at the rate of 25,000 per acre.

The pond was drained September 9th, and we removed 8,601 fingerlings, with an average weight of 3.23 grams and an average length to the base of tail of 2.7 inches; and also eight select fingerlings with an average weight of 32.5 grams and an average length to the base of tail of 4.51 inches. This gives a return of 49.8%, or 12,475 fingerlings per acre.

The cost of labor was $130.00 per acre, and the cost of manure was $25.00 per acre, making a total of $155.00 per acre, or $12.40 per 1,000 fingerlings.

In pond No. 5 the Daphnia were cultured from trout excrement on the bottom of the main pond. The area of the pond was .60 acre. The bottom of the pond was covered with a thick layer of excrement produced by 15,000, eight to ten-inch brook trout which were wintered in this pond for eight months. In this method, care must be taken to see that the decomposing excrement does not reduce the oxygen content of the water to a critical point. There was an average of 33.4 grams of bottom food per square meter, and an average of 174 grams per cubic meter of plankton food.

On June 14, 1932, the pond was stocked with 13,356 smallmouth bass fry, at the rate of 22,130 per acre. The pond was drained September 13, 1932, and we removed 5,480 fingerlings with an average weight of 9.76 grams, and an average length to the base of tail of 3.2 inches. This gives a return of 41% or 9,130 per acre.

The total cost, entirely labor, was $50.00 per acre. This gives a cost of production of $5.47 per 1,000 fingerlings.

Although the percentage return was lower by this method, the bass were much larger and the cost of production was much lower.

Conclusions

1. The method used in Pond No. 5, i. e., Daphnia cultured from trout excrement in the main pond, is the most practical method of raising bass where this is possible. This pond produced larger fingerlings at smaller cost than the other two ponds, although the numbers were not so great.

2. In the above method great care is necessary to prevent the dissolved oxygen supply from becoming exhausted.

3. There seems to be little choice between the other two methods. While construction of separate Daphnia ponds would be an added expense, this would probably be overbalanced by a longer and more continuous supply of Daphnia, and by the opportunity for closer observation and control.

TABLE OF DATA

	Pond No. 11	Pond No. 10	Pond No. 5
Cost of labor per acre*	$148.50	$130.00	$50.00
Cost of manure per acre	$25.80	$25.00	----- ---
Total cost per acre	$174.30	$155.00	$50.00
Stocking rate per acre	25,000	25,000	22,130
Fingerling obtained per acre	12,990	12,475	9,130
Per cent return	51.8	49.8	41.0
Ave. weight of fingerlings in grams	6.48	3.23	9.76
Average length of fingerlings in inches to base of tail	2.88	2.70	3.20
Grams bottom food per square meter (average wet weight)	18.7	23.5	33.4
Grams plankton food per cubic meter (average wet weight)	278†	21.8	174
Cost per 1,000 fingerling	$13.40	$12.40	$5.47

*Cost of labor figured at 50c per hour.

†Very large per cent Volvox (no food value).

NOTES ON MONTANA GRAYLINGS AT THE PITTSFORD, VT., EXPERIMENTAL TROUT HATCHERY

RUSSELL F. LORD

United States Bureau of Fisheries Station, Pittsford, Vt.

The Montana grayling is a fish well loved by those favored anglers who have cast their flies upon his native waters. Like others of his high-finned kind, he dashes upward to a feathered lure in willing haste, and stung by the hidden barb tries his courageous best to undue the fatal rise. He has everything that a true game fish should have—beauty, rare beauty of line and color, speed, grace, courage—and a place in the frying pan second to none.

It is not surprising then that such a species should have received considerable attention in fish cultural circles. According to the records of the bureau, artificial propagation of the Montana grayling took place for the first time in 1898. Dr. James A. Henshall, our well-remembered friend, then superintendent of the government hatchery at Bozeman, Montana, described the culture of the grayling in the Report of the Commissioner of Fisheries for 1906. He summarized here the output of the station from 1898 to 1907 inclusive.

Since then the work has been carried on by both government and state, and we are very glad to know that these efforts were successful in establishing the grayling in many Montana waters where it was not indigenous. Most of the work consisted in the collection of eggs from wild fish and planting after eyeing or as unfed fry. Due perhaps to the availability of wild stock to supply enough eggs and to the doubtful success in rearing a brood stock of adults, few attempts were made to carry graylings through to maturity. That it was possible to rear graylings to maturity and take the eggs, however, was demonstrated by Dr. Henshall for a few seasons at the Bozeman station, but in recent years the practice of rearing graylings beyond the advanced fry size is unpopular with the Montana State Commission, which deems the results quite unsuccessful when compared on an equal basis with the propagation of trout. And yet, despite the reputed good results with the type of propagation mentioned earlier, the Montana grayling is reported to be in a bad way in his home state, with his numbers on the wane. He needs help.

Such was the situation when the bureau's hatchery at Pittsford, Vt., was turned over for research in trout culture. As part of the program outline was the investigation of non-indigenous species of fish whose propagation appeared to offer certain difficulties, it was

decided to try out the grayling in Vermont. A paper on the grayling in the East (Laird, 1928) had already been presented before this Society. Laird's results made us even more interested to see if his success in the rearing of grayling could be duplicated in another eastern environment.

Accordingly, arrangements were made for a shipment of Montana grayling eggs which were received at Pittsford, Vt., on June 24, 1929. Credit is due to the shippers, for the eggs survived a trip of six days and arrived in excellent condition. Hatching began two days after arrival and by the second of July the hatching was at the peak. Then things began to get interesting. We were not equipped to handle such tiny fry and they straightway went through our finest screens until we stopped them by tacking on some cloth to keep them in the troughs. The minute size of the fry also offered feeding difficulties, but this was overcome by grinding beef liver as fine as possible and straining it through the finest wire mesh obtainable. This was no new procedure but was all in accordance with information in Dr. Henshall's report of twenty-three years previous.

Nine days from the peak of the hatching the little graylings were feeding readily and from then on not the slightest difficulty was experienced in caring for the fish. It was early observed that the fish receiving brook and spring water mixed were doing better than the fish in straight spring water. So, with the exception of the fish that had already been taken outside and placed in natural spring-water raceways, all were reared in mixed water. This too was in accordance with Dr. Henshall's data, which stated that a good supply of creek water was better to use than spring water.

By the 22nd of August the fish had developed into fingerlings an inch and a half in length, and viewing the vigor with which they fed and the zeal and activity of all their movements, we candidly found ourselves wondering what was all the furor about the rearing of graylings. In short, the species were thriving and growing faster than trout of the same age.

These first observations agreed with the findings of Laird, who said that once started the graylings at his hatchery were more easily reared than trout. There is often a very high mortality in bringing trout through the early feeding stages but this was not noticeable in the lot of graylings. During the summer, however, it was necessary to treat the fish with copper sulphate to combat gill bacteria, but this is not a procedure confined to the rearing of grayling, as many of us, to our sorrow, well know. The graylings stood the treatment as well as any trout we have handled.

They wintered well and in the summer of 1930 some 4,000 were liberated as yearlings in one of the larger Vermont streams, and last season saw 1,000 more set free as two-year-old fish in the same waters. The planting of grayling attracted much local attention, as the species with its unusual appearance and enviable reputation ap-

pealed to the anglers' fancy. Various reports on the taking of these fish have been received during the Vermont fishing seasons of 1930 and 1931.

Enough of the fish were retained for a brood stock. Before I go into the results with these older fish, I would like to say that a brief description of the propagation of the Montana grayling at Pittsford came out in the Fisheries Service Bulletin for May, 1930. This gradually stirred up a great commotion in the Montana pool of grayling controversy and ripples were felt on either side as far as California and Michigan. A great deal of letter writing subsequently occurred in which I clung to my assertion that given a suitable water supply I did not see why graylings could not be reared as easily as trout. There appears to be a great difference of opinion on this matter in Montana.

To return to the brood fish. During the past winter the development of the sex organs was checked by dissection of specimens and it was seen that the fish would surely be spawning in the spring.

Accordingly, a few months ago on May 16, the graylings were removed from their wintering pond and sorted for sex and ripeness. Two-thirds of the females were found to be ready. None had as yet spawned. We were not greatly pleased, however, to find that we had a great preponderance of males in our stock, this being brought about by our zeal in retaining the largest fish with the most handsome dorsal fins. These proved to be the wrong sex for egg production.

The eggs were taken by the *wet* method, that is, being stripped into a dish containing a small amount of water. The milt was added, the male fish giving, as pointed out by Leach (1923) only very small amounts of milt. After washing, the eggs were transferred to Chase jars for incubation.

I am sorry to announce that the results obtained from this first take of eggs were very poor. Many reasons were suggested, such as the warming up of the water in the spawning dishes and the subsequent change to the cold spring water in the jars. Possibly it was poor fertilization or too much agitation in the jars during incubation. I confess it made me nervous to watch the grayling eggs as they slowly boiled; it was such a contrast to the quiet demanded from trout eggs at such a time. Whatever the reason, when the eggs were shocked on May 24 only a 7% eye was obtained.

We were more than a little dissatisfied with these results and determined to handle the next lot of eggs differently. Much to our disappointment only four more fish of the twenty-six remaining females were ripe at the next stripping, which followed a week after the taking of the first eggs. The remainder of the fish were clearly immature and would not spawn at this time.

The eggs from the four females were taken by the identical method we use in taking trout eggs. They were stripped into a

clean, moist pan, the milt was added and stirred up with a feather without the addition of any water until the eggs were washed. As soon as they were clean they were transferred at once to a hatchery trough equipped with the same kind of brook water in which the adult fish were being held, and allowed to incubate in a thin layer on the bottom of an ordinary hatching basket.

Examination with the microscope a few days later revealed a much better fertility than with the first eggs, and on the third of June the eggs were shocked. We were greatly pleased to find that as many good eggs were obtained from four fish handled in the fashion mentioned as from fifty-five females handled by the previous method. The number of fry hatching was approximately 70%.

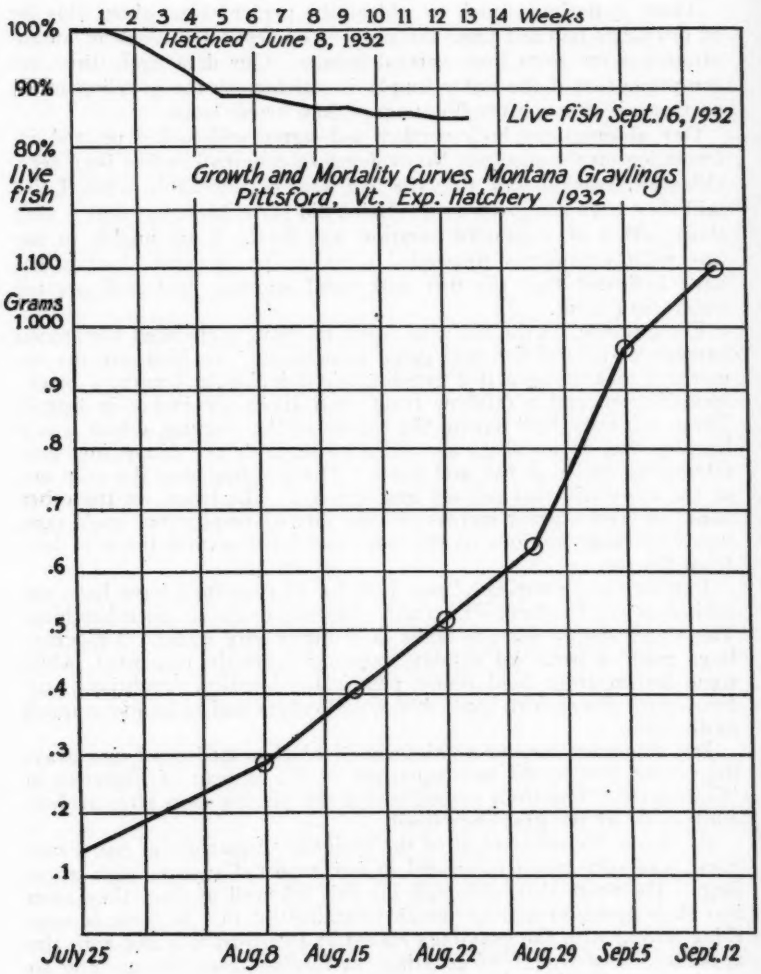
The fry were swimming up on the eighth of June. They were exceedingly active. When offered food they refused it, but it was presented frequently until two days later some of the little fellows appeared interested enough to look it over, although none were seen to take it. The next day, however, they began to snap up and retain the particles of food. From this time on the fish fed willingly and by the middle of June were taking their liver with eagerness. It was quite entertaining to see a floating particle of liver suddenly disappear between two golden eyes which were just about the only visible features of those tiny fry.

The silt and surplus food that collected in the bottom of the trough was removed by siphoning with a length of small-diameter rubber tubing. The fry were quick to avoid the hand of the operator and few were ever sucked into the tube. Their habit of swimming very high for the first week or so helped in this respect.

The following growth and mortality curve shows the development of the fish very nicely. As the grayling fry are such insignificant creatures on hatching, the growth is quite astounding to those accustomed to the development of trout.

The fish are still being carried in a standard hatchery trough supplied with straight brook water. The temperatures taken on twenty-four occasions averaged 59.6° F.

Contrary to expectation, an examination of the contents of the water strained through a plankton net for a three-hour period on August 9 revealed little actual volume of natural food being carried with the water. Of the typical plankton there were none. Small midge larvae and now and then a pupa, tiny mayfly nymphs, simulium and a few nematode worms were present, but in such small amounts as to constitute an insignificant item in the daily menu of over 5,000 grayling fingerlings. There was considerable detritus composed of bits of vegetable matter, earth and an abundance of the chitinous fragments of various aquatic insect larvae. These appeared to be more in the nature of shed-skin fragments than pounded up pieces of the whole animals. The stuff did not look a bit nourishing. It would appear therefore that the success of the graylings in the


1 2 3 4 5 6 7 8 9 10 11 12 13 14 Weeks
100%
90%
80%
live fish
Hatched June 8, 1932
Live fish Sept. 16, 1932
Growth and Mortality Curves Montana Graylings
Pittsford, Vt. Exp. Hatchery 1932
1.100
Grams
1.000
.9
.8
.7
.6
.5
.4
.3
.2
.1
July 25
Aug. 8
Aug. 15
Aug. 22
Aug. 29
Sept. 5
Sept. 12

brook water is more a matter of favorable temperature than additional food.

There is nothing much to add at the present time about this lot of graylings hatched from the eggs of domesticated stock in an environment far from their natural haunts. Our data again this season prove that if the water supply is satisfactory the grayling offers no more, if as much trouble, to rear than brook trout.

Our observations both conflict and agree with other printed information on the species. No evidence of cannibalism has been seen, although Henshall said that the fish were of this habit, while Laird said they were not given to it. Laird did state, however, that a very short period of suspended aeration was fatal. I am unable to say just what constitutes suspended aeration, but several observations have indicated that the fish will stand warmer, less well aerated water than trout.

For instance, on the night of April 16, 1931, I attended the annual banquet of a local fish and game association. To illustrate my remarks I took along a live grayling eight inches in length, a blackspotted trout and a rainbow trout each about six inches in length. These fish were held during the course of the evening, which was a lengthy one, as evenings are when enthusiasts are discussing such interesting topics as fish and game. The grayling was the only one of the finny trio that seemed undistressed. The trout, on the other hand, showed a great increase in the rate of respiration, made convulsive jerking motions of the head and tried several times to leap from the jar.

Furthermore, samples of our 1929 lot of graylings have been exhibited at the Rutland, Vt., county fair every season since hatching. The water supply for the tanks is ordinary city water. The graylings made a beautiful display, seeming perfectly contented, while some brown trout held under practically identical conditions suffered great discomfort, some dying, and others had to be given much more room.

Just this past summer a shipment of blackspotted trout and graylings were sent to the new aquarium of the Bureau of Fisheries in Washington. The trout passed out of the picture soon after arrival, while most of the graylings lived.

Mr. Seale, Superintendent of the Steinhart Aquarium in San Francisco, was very much interested in our reported success with graylings. He wrote that, although his fish fed well at first, they soon lost their appetites and too much mortality set in. If there is anything wrong with the graylings reared at Pittsford it is not with the appetites. Our trough of graylings at feeding resembles nothing so much as a collection of tiny sharks, twisting and turning with white bellies flashing as each one tries to get there first. A visiting trout culturist watched the antics recently and said, "those are the craziest

fish I've ever seen." Our various trout fingerlings in comparison feed very sedately.

As a fish cultural proposition, therefore, the grayling to me seems a most reasonable fellow. The fish handle nicely, being less inclined to struggle than trout at stripping, and the eggs come easily. While being held in outdoor compartments sixteen feet long by five feet in width they showed little desire to fight the screens in an effort to go up stream. Brook, rainbow and blackspotted trout held to ripen in these same pens will batter themselves considerably when not prevented by adequate barriers. The graylings on the other hand behaved sensibly.

As to the possibility of the species getting established in some Vermont stream, that remains to be seen. They were unfortunately given no extra protection and Vermont fly fishermen are legion and experienced. Our young fish will of course be reared to maturity, and if nothing goes wrong with our adults by next spring we anticipate many thousands of additional youngsters for coming experiments. The brood fish, by the way, are being held in the warmest pond available at the station, where temperatures as high as 74° F. were taken last season without any mortality appearing among them.

They apparently enjoy it, and they enjoy too each grasshopper tossed them by admiring visitors, never failing to show their appreciation as the hopper vanishes in a dash of spray and a flash of silver. And I ask you, gentlemen, could ignoble insect come to a more glorious demise?

Discussion

MR. FOLLETT (Michigan): I think the term "flower of fishes" was first applied by the Jesuit fathers to the Michigan grayling. It is a question whether there are any Michigan grayling left today. In that connection Dr. Hubbs, I understand, is going to follow up some experiments on the Otter river in the upper peninsula, the only stream where grayling are found today. I was up there about ten years ago trying to get some breeding stock, and I was guided by my old friend, Seymour Bower, and by Dr. Henshall as well. On the first of May when I arrived at the creek the fish had all spawned; we found that the Michigan grayling spawned earlier in the upper peninsula than in Montana, probably in the month of March, when it would be impossible to capture the wild fish. I went up later and fished with a fly for a couple of days, but to my disappointment I got only one Michigan grayling; the other twenty were all Montana grayling that had been introduced by the Michigan Fish Commission some years before. I am inclined to doubt whether the Otter river contains anything except Montana grayling.

MR. CULLER: I was much interested in Mr. Lord's experiments, especially where he said the grayling could be reared as easily as trout, because that coincides with some experiments we have carried on at several of our stations. When Mr. Bronson was Superintendent of State Fisheries in Montana, in 1922-23, we had the same experience. When Mr. Hoofnagle was carrying on work in

Montana he made experiments in the hatching and rearing of a few graylings. Three years ago we had a shipment of grayling eggs sent to La-Crosse. We reared them to two inches in size, but we could not get them any larger. For some reason they gradually dropped off until there were only approximately 100 left. We put them in a pond and they disappeared. What Mr. Lord has said coincides with our view that grayling are just as easily reared as rainbow or brook trout.

MR. LAIRD (Long Island): We had some grayling which, strange to say, lived very nicely among the smelt and other kinds of fish in brackish water where the tide was rising and falling. Fishermen caught some of these grayling and brought them around, wondering what they were. In one pond I planted six or seven thousand Montana grayling and raised them to twelve to fourteen inches long, but we discontinued them because the members could not catch anything else.

DR. CARL L. HUBBS (Director, Institute for Fisheries Research, Michigan): To our knowledge no really clear-cut distinction has ever been made between Michigan and Montana grayling. Milner and Henshall both listed differences, most of which, however, we fail to confirm.

The grayling are clearly subject to great variations, with age, sex, season, locality and probably individuals. What the actual differences may be between the Michigan, Montana and Arctic graylings is very difficult to decipher from the published accounts.

We would very much prefer to base our account on an original examination of specimens. Unfortunately our material is limited.

Comparison fails to indicate any differences between three old specimens from the southern peninsula and those collected about 1922 and in 1925 in the Otter river. So far the evidence favors the conclusion that the Otter river grayling are native. There can be little question that Michigan grayling *are* native in the Otter. Jordan and Evermann in 1896 wrote of having specimens from that stream.

The distinction of the Michigan grayling from the Arctic grayling seems valid. The northern form has a longer dorsal fin with more rays becoming much higher with age.

The Michigan grayling was claimed by Milner and by Henshall to differ from the Montana grayling in a number of characters of form, proportions and color. Most of these characters do not seem to hold very well.

The conclusion seems verified that the Otter grayling in the Otter river in 1922 and 1925 were natives, and probably that those still remaining are also of the Michigan species.

This conclusion, however, is still tentative, because of the confusion in published accounts, and the scarcity of material for new comparisons. A further study of this problem will be made at the U. S. National Museum where many specimens are preserved. In the meantime, an effort will be made to obtain more specimens from Montana.

MECHANICAL DEVICES USED IN MICHIGAN FISH CULTURE

A. B. Cook, Jr.

Field Superintendent of Fisheries, Michigan Conservation Department

Some one has said that the only constant factor in the world is change. The validity of this statement is apparent when we analyze the tremendous changes which have been wrought in everyday life by the advent of the machine.

Until a few years ago, the railroad was the chief means for transporting fish from hatcheries to distant lakes and streams, due to lack of other satisfactory means of transportation and road conditions. At that time, almost all of the various tasks connected with fish culture were performed by hand because the machine age had not penetrated this field to any degree.

In recent years, the fisheries work in Michigan has faced several serious problems. Extension and improvement of highways and roads has made the waters more accessible to the public and intensified the need and demand for restocking. The present well established policy of rearing fish to larger size also contributed to this problem to a marked degree. Automotive competition, made possible by modern highways, has forced railroads to curtail service to such an extent that systematic distribution of fish by that medium is all but impossible. Demands of the public for greater economy in government, linked with a serious reduction in revenue from established sources, placed the Fisheries Division in an embarrassing position.

With these problems in mind, the entire force of the Division made a concerted effort to hold up production in spite of a reduced operating budget and, after several years, I feel that some of this work has developed to a point where it can fairly be presented to the Society.

Our experiments and researches have proved the possibility of nearly doubling the capacity of the individual man in caring for fish in troughs. The problem of grading fish to size has been successfully dealt with, and that ever present problem of transportation has been reduced to a minimum.

Not all of the devices treated in this article have been adopted for all of the hatcheries of the state, but we are confident that, within a short time, they will be in general use at nearly all of the important stations.

One of the outstanding factors in caring for small fish in troughs or tanks is that of cleaning. Mr. A. J. Walcott, who has charge of the Fisheries District with headquarters at Harrietta, went into this

problem very thoroughly. He found that under ordinary conditions, a man armed with the conventional tools could care for no more than fifty troughs in a day under conditions comparable to those at Harrietta. By the use of a water suction cleaner this same man cared for 100 troughs. This cleaner consists of a centrifugal pump with three-quarter inch suction and one-half inch discharge powered with a one-quarter H.P. electric motor mounted on a cast iron base, which in turn was placed upon a small wooden cart. Attached to the suction end of the pump is a twelve-foot hose with a head similar to those used on a floor vacuum cleaner. A fine grating over the open end of the head allows the debris to be removed without danger to the fish. The intensity or force of the suction is regulated by a valve. This device is not recommended for use when fish are very young but is most effective when they are thirty or more days old. Its value increases with the development of the fish.

Various devices have been perfected for feeding fish, but I believe that Mr. Guy Lincoln of Oden, Michigan, has attacked this problem along completely new lines, and has perfected a very practical automatic feeder which injects the food into the water supply pipes leading to the hatchery troughs. However, this particular type cannot be adopted where head troughs are used. This automatic feeder consists of a funnel shaped hopper and a trap made of one-half inch elbows and nipples. This is connected to the trough water supply pipe at a point approximately one and one-half feet below the troughs. Water is supplied directly to the hopper by which the rate of operation can be regulated inasmuch as the amount of water added forces an equal volume of food and water through the trap.

A small gauge glass mounted in the feeder pipe makes visible the amount of food being supplied and insures operation. Stoppages are surprisingly few, especially if water in large quantities is added to the food during grinding. Constant feeding of small quantities of food keeps all fish seemingly satisfied and also provides food several hours after the attendant has left for the night. For these reasons, we are of the opinion that these feeders are of advantage even though they did not save on labor, but we have every reason to believe that they will pay for themselves and effect a saving of over $500 at Oden station this year.

The old method of grading fish by hand was a tedious process. For several years past most hatcheries have used the parallel bar type of fish sorter which works very well for that purpose. The fact that the bars are permanently spaced does not permit adjustment for fish of different size, which necessitates the construction of sorters of various sizes. It has long been a contention that an automatically adjustable grader would be of material aid to fish culturists. Mr. Walcott worked on this problem and has perfected a device which has proved to be practical and efficient.

The first grader consisted of an aluminum frame 12" by 18" and

about 10″ deep. At a point about six inches from the top of the frame twenty-four three-eighth-inch glass rods are suspended in a slot and separated by tapered spacers which are controlled by a hand screw. Hinged ends, which are held tightly by springs, allow the parallel rods to be spread to any desired spacing from one-sixteenth to one-half inch. With this equipment it was possible for two men to grade into three sizes 120,000 trout fingerlings at Bear Creek Station in one day without injury to the fish. Similar results have been obtained at other places. Recently, graders of this type, but much larger in size, and equipped with floats to allow them to be used in ponds, have been perfected. Although still in experimental state, we are convinced that they will prove very effective.

In addition to these devices, we have utilized with marked success many commercial machines. Among these are power lawn mowers (at one of our stations one of these machines saved its purchase price the first month of operation), painting machines, pumps for pond cleaning, etc. We have also used the Grammes egg counter device, the screen cleaner which was perfected at New York's Dunkirk Hatchery, and many other pieces of equipment perfected and used in other states.

During the past several years, efforts have been concentrated on solution of the transportation problem. The difficulties of transportation by rail, due to curtailed service, and the fact that production of large fish was greatly increased, made this of paramount importance. From 1,000 to 2,000 trout fry could safely be transported in a ten gallon can, whereas the same can could carry no more than fifty to 100 advanced fingerlings.

Almost all possible combinations of heavy and light trucks, trailers and semi-trailers, tanks, buckets, and cans were tried. After intensive study it was decided that a light truck with tandem rear wheels most nearly met all of our conditions. It is true that heavy trucks with dual wheels work very well on good highways, but they proved to be almost useless on unimproved sand roads. Experience proved that power in both rear wheels was necessary under certain conditions, therefore, in the more recently constructed units, Twin-Flex units with sprockets and chains are installed. A standard one and one-half ton Ford or Chevrolet chassis equipped with a Twin-Flex unit will successfully carry a load of over three tons.

Tanks for carrying live fish of larger size were found more efficient than cans. The method of aeration was the next problem, and a circulating system was chosen for several reasons, although an air compressor can be installed on the present units if later determined advisable. Various types of pumps were tried in addition to considering the use of pumps powered from the truck motor. A small centrifugal pump with automatic primer, capable of delivering 100 gallons of water per minute if the lift is not too great, powered by

a three-quarter H.P. four cycle aircooled motor with starter, was finally chosen.

The evolution of the truck, tank and pump combination may not be of interest to you, but possibly the latest development in this connection may be.

A tank built of ten gauge copper bearing steel 116 inches long, 43 inches wide and 30 inches deep was constructed upon a chassis of the type already described. This tank was divided into four compartments, with an eight inch stand-pipe running crosswise in the center. The sides, bottom, and covers of the tank are insulated with two inches of ground cork which is held in place by sixteen gauge plates. Water returns to the stand-pipe by gravity which insures uniform depth in all compartments. Check valves prevent surge or piling of the water while on unlevel roads. Plates in the top of the compartments prevent water from splashing out around the covers. The bottoms are covered with a perforated metal sheet which is supported two inches above the floor, and thus prevents the fish from entering the suction line. This suction line is merely a duct which runs from the stand-pipe underneath the screen forward to the pump, which is located in a compartment directly back of the cab. The pump's discharge is connected to two pipes which run either side of the central partition of the tank, containing one thirty-second of an inch holes through which the water is jetted back into the tanks, from almost any source. By the same method one can change the water on the fish or temper the water upon reaching the lake or stream. This would be impossible if air alone was used.

Temperature is controlled by placing ice in the stand-pipe. By this method it can be held at any desired point without bringing ice in contact with the fish.

This unit carries a normal load of 500 gallons of water (its maximum capacity is 600 gallons) and the weight of the tank is about 1700 pounds.

The initial cost of this type of carrier is not excessive. The chassis equipped with a Twin-Flex unit costs between $800 and $900. The tanks were built by a concern which specializes in tank and boiler work for $600 each. Pumps equipped with self starter may be purchased at a cost of approximately $200. Total cost is in the neighborhood of $1700.

Economy is apparent when we consider the fact that the entire first cost is about the same as that of an ordinary three-ton truck. The operating and upkeep costs are only slightly in excess of those of standard one and one-half ton trucks.

To date it is impossible to give accurate data as to the number of fish of various sizes that these units will carry. At the present time, a vast amount of material on this problem is being assembled by the operators of these units. Careful check of numbers and weight of fish transported, water and air temperature, humidity and atmos-

pheric pressure, mileage travelled and time on the road are being kept. All of these factors seem to have bearing on the problem and we hope in time to have some accurate information in that regard.

The practical experiences which we have had with these units lead us to believe that we are not extravagant when we contend that they will easily carry four times as many fish as can be transported in small trucks carrying capacity loads of thirty ten-gallon cans. Recently 15,000 bass fingerlings were conveyed to the Upper Peninsula, a distance of 500 miles involving eight hours on railway car ferry across Lake Michigan. The fish reached their destination in excellent condition. We would not attempt to make a trip of this length with small trucks and cans as conditions of temperature and aeration would make it prohibitive. Railroad service is such that the fish car would require more than one trip to move the same number of fish. We believe that the tank truck here described has reduced the limiting factors to a minimum and that the quantity of water used will successfully carry as many fish as can be carried in a like amount of water in any type of container.

Certain accessories have been installed in the case of our most recently constructed units. These include an electric starter for the pump, a thermometer which records water temperature, the dial which is located in the instrument panel of the truck and a pressure gauge which keeps the operator informed as to the efficiency of his pump at all times. A folding desk which contains such instruments as psychrometer, barometer and thermometers as well as necessary records has been built in the recess back of the cab and opposite the pump. A "cat walk" with "drop sides" makes a ledge capable of carrying thirty-two regular ten-gallon cans. This is advantageous if one wishes to relay small quantities of fish.

In addition, this tank assembly can be removed from the truck chassis and an oversize platform installed quickly which will permit use of trucks for ordinary purposes such as transportation of the common ten or twenty-gallon fish shipping cans. The latter are still being used in the distribution and planting of whitefish and pike-perch.

In concluding, I might state the few mechanical devices mentioned here do not by any means exhaust the list of experimental types in operation in our state nor does this article take into consideration the matters of added efficiency which necessity has brought us in the fields of construction and what one might properly call, improved methods. There is no hatchery head in the state today who is not working on some plan to improve the efficiency of his station as well as all of the activities of the Fisheries Division.

Discussion

PRESIDENT RODD: I understand that you can supply anyone here with blueprints and full descriptions of anything you have dealt with?

MR. COOK: I have some pictures that those present might like to see.

DR. EMBODY: Do I understand that the tank is divided into compartments?

MR. COOK: Yes, it is divided into four separate compartments. Perhaps I did not make myself clear on the operation of this particular unit. A suction hose can be attached to the pump so that you can pump the water directly from the stream or lake or wherever you are going to plant your fish, and by opening a bilge cock in the middle of the tank the water can be removed so that you can pump the water at any rate you may wish into the tank to replace that in which the fish are being carried. Each compartment can be operated separately. The water can be cut off on any one or removed from any one; you can empty half or quarter of the tank and still have the other half or three-quarters in operation.

DR EMBODY: If you are planting trout, for instance, along a stream, putting a few here and a few there, how would you distribute them.

MR. COOK: We have a device I did not mention—it is still in the experimental stage—and I think Mr. Hayford has a similar system; a kind of boat that weighs forty-five pounds and that a man can throw over his shoulder and plant the fish from it. In a letter I received since coming here I am advised that they were hauling 27,000 four to six-inch fish to the streams at a load, and without any trouble. We also use it extensively for the transfer of migrating rainbows when they come up to the big power dams in the Muskegon, and the Manistee river more especially, and we have been able to carry almost unbelievable quantities safely. That pump does not operate all the time, or anywhere near all the time, but only about three to five minutes to the hour. It is operated by a little gasoline motor, more efficient or desirable than any other kind of motor we could get. It has an automatic primer so that you can pump water right out of any source.

MR. COWDEN (New York): When you are delivering your fingerlings in tanks of this kind, how do you arrange for cans for the applicants to plant the fish?

MR. COOK: We do not distribute fish to applicants in our state; we discontinued the application system a few years ago. Of course it may occasionally be desirable to load about thirty cans on the side of the truck and turn these over to people who may relay them to distant points, but for the last four years, I believe, the state has planted all the trout, not taking them to applicants at all.

EXPERIMENTS IN THE PROPAGATION OF SPOTTED BLACK BASS

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Results shown by propagational studies in Ohio indicate clearly that the rearing of spotted bass is still in an experimental stage. Although much has been observed during the past year, nevertheless many difficulties are manifest. The fish lends itself so favorably to hatchery conditions in many ways, while in others exactly the opposite is true. Hence it is our purpose to discover a happy medium in which the fish can be reared most successfully.

In order to comprehend the situation accurately we should first note the advantages and disadvantages in the rearing of the spotted bass by the present methods. The advantages are: (1) the short incubation period, (2) probability of one spawning period before reaching legal length, (3) vitality of the fry when only three or four days old, (4) freedom from parasitism and resistance toward funguses and plant growths, and (5) uniform growth rate. Disadvantages number: (1) difficulty in retaining fry in spawning stalls, (2) difficulty in preventing fry from passing from one hatchery pond into another through the screens guarding the conduits between them, (3) the difficulty in feeding them cut or ground fish in the usual manner, (4) the poor results obtained in cold water, and the trouble in holding the breeder fish over the northern winter.

In the spring of 1932, 132 wild breeders were placed in Newtown hatchery. These were first located in a separate pond, but probably due to the frigidity of the water, did not spawn. Later these were transferred to a larger breeding pond having a warmer temperature, and mixed with smallmouth also of breeding size. In a few days when the water temperature reached a minimum of 64° both species started to spawn. This occurred on May 14th, 15th, and 16th. From the total number of breeders numbering eighty-nine at that time, sixteen beds of eggs were obtained, nine within the spawning stalls and seven wild. The nests were of varied sizes and shapes ranging from those built on the mud bottom of the pool in four feet of water to those on the gravel at the edge of the pool in nine inches of water. The nests built on the gravel in the shallow water were protected, while those in the deeper water were open. The shallower ones were either in the spawning stalls or under the overhanging grass at the edge of the pool. Two unusual cases were noted. The first was the presence of both smallmouth and spotted bass within the same stall.

The second was noted in a spotted bass fighting with a smallmouth over the same bed, the latter being victorious. However, when the eggs hatched, young of both species were found hovering over this bed.

The fry in the spawning stalls were transferred between the ages of four and six days. However, due to their small size and surprising agility, a large number escaped from the stalls, passing either through or around the screens. Later these fry and also those from the wild beds outside the stalls were seined out of the pool and transferred. It is estimated that 31,000 fry were taken from the sixteen beds in the pool, this showing an average of approximately 2,000 fry per nest.

After having placed them in rearing pools it is almost impossible to retain them there. The fry pass through the screens guarding the conduits connecting the pools with such ease that within a few days young bass were found almost all over the hatchery.

The young fish were fed on cultures of Daphnia, etc., in the water of the pools. As soon as they reached a size approximating an inch, attempts were made to feed ground fish to them but with no results. Although continued attempts were made from that time on, no evidence was shown of the fish taking the food. This in itself forms the most difficult problem in the rearing of this fish.

For a clear understanding the food cycle of the wild fish should be noted. At an early age the fry subsist upon entomostraca of the commoner sorts, the species varying with the locality in which the fry are found. Later the diet changes to insect food for the most part, with small crustacea oftentimes found. This gradually works into one in which crayfish and large insects predominate. In very few cases were wild fish found living either partially or totally on a minnow diet. From feeding experiments crayfish are from three to four times more acceptable than minnows, while insects were shown only a slight preference. Small leopard and pickerel frogs were taken only when other foods were exhausted. Hence in a form such as this which does not show a decided liking for fish as food, a substitute must be found if propagational success is to be assured.

The examination of hatchery fish show the same types of food predominating. The diet, entomostraca to insects to crayfish and allied forms, remains the same. This explains the diffculty in forcing them to take the ground fish. It was not until the second year that the yearling fish would accept it as food, and then only because they were starved to it. If means were found to rear crayfish for food, there would be but little doubt as to satisfactory results.

Experiments show that early morning and late evening are the most favorable times for the feeding of spotted bass in hatcheries. Fish digestive tracts examined in the morning showed a full or partially filled stomach and intestine. The intestinal food was indicatory of evening feeding as the insects contained were those digesting

and breaking up easily. Fishes examined late in the afternoon show an empty stomach and partially filled intestine, indicating that very little feeding is carried on during the day.

Lights were placed over experimental stalls in the hatchery to attract insects, while other stalls were kept in darkness as a check. Fishes taken from beneath the light showed full stomachs and partially filled intestines, while those in the check stall were almost completely empty. This points out one method of feeding the fish with fair success. Ohio plans to raise part of her spotted bass during 1933 by this means.

The digestive tracts contained divers forms, insects predominating. These were adults and larva of mayflies, mosquitos, midges, dragon flies, damsel flies, and back swimmers (*Notonectidae*). Beetle larva only were found. Adults of wasps, grasshoppers, and flies were noted. Of other forms taken, isopods, ostracods, water fleas, copepods, and annelids made up the dominant portion. Six stomachs out of sixty-one examined contained fish. This indicates either a slight liking for fish or a scarcity of fish. The latter possibility is to be doubted, as the fish are fed ground fish every day, and also a large number of goldfish breeders live in the pool. The following table indicates the ratios of the forms found based on numbers of individuals of each type. This is important in that each form means an attempt made by the individual fish. It was not possible to make up a quantitative chart in regard to bulk as the forms had such varied sizes.

TABLE SHOWING FOOD OF THE SPOTTED BASS

Midges	**77.5%**
Midge larva	**4.7%**
Mosquito larva	**3.8%**
Mayfly larva	**2.6%**
Mayflies	**1.6%**
Damsel flies	**1.7%**
Ostracods	**3.5%**
Miscellaneous	**4.6%**
	100.0%

Attempts were made to force the fishes to take cut food but with little success. All feeding of this sort observed was directly from the moss on the bottom. As observed, a probable 5% of the fish take this type of food, the majority of these being the larger fishes of this year's hatch. It is assumed that the fishes might be divided into two groups according to size and feeding habits. The larger ones ranging from five and one-half to seven inches in length take the cut food, while the smaller ones ranging from three to five inches in length live on natural food. This was corroborated to a

fair degree from an examination of stomachs immediately after feeding. Experiments were made to attempt to starve the smaller fishes to taking the food but too much natural food abounded for any success along this line.

Spotted bass placed with smallmouth in the pools, feed a bit more readily than those living by themselves. This is probably due to the example or competition of the smallmouth. On September 12, 1932, the fishes in a pool with the smallmouth averaged almost an inch more in length than those living alone. The former ranged from five to six inches, the latter from three to four inches. However, too much encouragement should not be taken from this observation until it is conclusively known that the larger smallmouth do not eat the smaller spotted bass. In such a case the assistance rendered at first might be detrimental in the end.

Night feeding of the fish has been attempted, but it is difficult to estimate the success of this method. Fishes fed at 7:30 in the evening (just before dark) and 8:00 in the morning were found to contain more of the ground fish than those fed at other times. The most of this food was taken at the evening feeding. This is indicatory of night feeding habits for the most part. The ratio of the natural and artificial foods is still problematical as the results of these experiments indicate a decided dominance of the wild food.

The above experiments illustrate the problems which confront the fish culturist in the rearing of these fishes. Many difficulties are still to be overcome, but during the next few years it is hoped that Ohio may be able to place the spotted bass upon the same propagational standard that is now occupied by the large and smallmouth basses.

THE USE OF DRY FOODS IN THE DIET OF TROUT

H. S. Davis

U. S. Bureau of Fisheries

Several years ago it was my privilege to present a paper before the Society on this subject but I feel that since that time sufficient additional information has been obtained to justify bringing the matter to your attention once more. In view of the results of our experimental work during the past few years I am convinced that trout culturists are making a mistake in not resorting more generally to the use of dry products. Many are still feeding raw meats exclusively and where dry foods are used it will be found that, for the most part, only cereals or products of similar nature are being utilized. In most cases the inclusion of dry foods in the trout ration has been adopted purely as a measure of economy and not as a means of producing better fish. In fact, it is the general belief among trout culturists that nothing can equal a straight meat diet. Comparatively few realize that by the use of animal meals they can produce better trout at less expense than can be produced on any of the fresh meat diets in common use.

When we began our feeding experiments our ultimate goal, which I confess seemed very far from attainment, was to produce fish which would grow as rapidly and would be in every respect the equal of the wild fish found in our best trout streams. This goal has been reached and I have no hesitation in saying that so far as color and hardiness are concerned just as good fish can be produced on artificial foods as are found in our streams and that in rapidity of growth hatchery fish will greatly excel wild fish except under most exceptional conditions.

Possibly I should digress here a moment to emphasize the fact that this statement is not to be understood as implying that I am in favor of the hatchery production of fish to the exclusion of natural propagation. Far from it. In many respects the artificial propagation of trout can never equal the natural process and no stone should be left unturned to encourage natural propagation in every way possible. In most localities artificial propagation should be looked upon as supplementary to natural propagation and not as the principal factor in maintaining the trout population.

Everything considered, the best food which we have as yet found for trout is dried salmon eggs. This product, which is manufactured from the roe of salmon used for canning, is notable for the fact that it produces a brilliancy of color which has hitherto been found only in wild fish. Trout culturists long ago noted the fact that the food

had considerable influence on the color of fish reared under hatchery conditions, but in no case did the foods then in use produce colors even approximating those of trout under natural conditions. Naturally the effect of salmon eggs on color is most noticeable in yearling or older trout, but even fingerling brook trout in the hatchery troughs when kept on a diet containing salmon eggs will usually show red spots before the summer is over. The effect on the coloration is perhaps even more noticeable in rainbow trout, where the bright green backs and brilliant pink and orange shades on the sides are in striking contrast to the dull colors of fish reared on the ordinary hatchery diets. Experiments during the past summer show that dry haddock roe has a similar effect on the coloration and of special interest is the fact that eggs packed in carbon dioxide give a much brighter coloration than those packed in air.

In addition to its effects on coloration, salmon egg meal produces a remarkably rapid growth and the fish are exceptionally healthy and vigorous. In fact, in our experiments during the past three years the fish which have made the most rapid growth, whether fingerlings or yearlings, have invariably been those on diets containing salmon eggs.

Other products which are of special value as trout foods are the better grades of fish and meat meals and dried buttermilk. These should be dried at a low temperature in order to preserve the vitamins as far as possible. Trout fed some of the meat and fish meals will grow nearly as fast as those on a diet containing the same amount of salmon eggs but none of them show the brilliant colors of the latter.

Most commercial hatcheries feed large quantities of cereals or beans. Although we have tried these products many times with both brook and rainbow trout, in no case have they produced results at all comparable with those obtained with animal meals. No doubt these products, especially when cooked, do have some food value, but it appears that their most important function is to provide roughage and to absorb and retain the meat juices which are otherwise largely lost. Of course these products have the merit of cheapness and in these days, when trout have almost become a drug on the market, this fact cannot be ignored. However, even with this advantage I doubt if there is any real economy in feeding these products, especially where fish are being reared for stocking purposes. For this purpose we need strong, healthy fish with plenty of vitality so that when liberated in natural waters they can quickly adjust themselves to the new conditions.

Recently McCay and his coworkers have found that cottonseed meal makes an excellent trout food when fed in combination with raw meats. Our own experiments with fingerling and yearling rainbow trout indicate that, while it is probably the best of the vegetable meals, it is not equal to the better animal products such as

salmon eggs or fish and meat meals. In fact, rainbow fingerlings on a diet containing 30% cottonseed meal made less than two-thirds the growth of those on a similar diet containing an equal amount of salmon eggs.

In the use of dry products it cannot be too strongly emphasized that they should always be fed in combination with fresh meat. Dry foods may eventually be developed which can be fed indefinitely without the addition of raw meat, but there is certainly no such product on the market today and any attempt to feed dry foods alone is certain to result in failure. The trout may do well for weeks or even months, but sooner or later they begin to die in large numbers and unless given some raw meat will all succumb within a short time.

As reported in the last volume of the Transactions, Dr. McCay* and his colleagues have kept trout on an all dry diet for over a year and we are ourselves experimenting with several diets prepared at the Birdseye Laboratories which so far have not resulted in any abnormal mortality. These diets, however, are manufactured by special methods designed to preserve the vitamins intact and are not yet available commercially. Furthermore, these all-dry diets have so far resulted in a considerably slower growth than in the case of those containing some fresh meat. Whether or not it will ever be practicable to keep trout indefinitely on a diet composed entirely of dry foods remains to be seen, but at the present time all such diets should be considered as on a purely experimental basis and outside the province of the practical fish culturist.

While apparently the most important function of raw meat in the diet is to provide some substance essential to the well-being of trout which is deficient or lacking in dry foods as ordinarily prepared, it should not be forgotten that it serves other functions as well. Anyone who has attempted to feed dry foods alone knows that it is almost impossible to get the trout to eat them without considerable waste. But when combined with the proper amount of raw meat it is much more palatable and the fish will usually eat the mixture with little loss. Too much attention cannot be paid to this phase of the problem since the success or failure of a mixture may depend on its consistency. If it disintegrates quickly in the water a considerable percentage will be wasted in spite of the greatest care in feeding.

The amount of dry products which can be safely incorporated in a mixture will depend on the size of the fish and the kind of meat used. On account of its consistency liver is more satisfactory for this purpose than heart or plucks. This is especially true of pig liver, which when ground is more sticky than either beef or sheep liver. For fingerlings, however, it is believed that beef liver will be found more satisfactory in spite of its greater cost, although with the larger fingerlings sheep liver will give nearly as good results.

*McCay, C. M., John W. Titcomb, Eben W. Cobb, Mary F. Crowell and A. Tunison. "The Nutritional Requirements of Trout." Trans. Am. Fish. Soc., Vol. 60.

For yearling fish sheep liver and pig liver appear to be equally satisfactory.

Owing to loss in feeding, the use of dry foods is not recommended until the fish reach a length of about two inches. Even with fish of this size there is danger that they may pick out the meat, leaving the remainder of the ration uneaten. It is obvious that there is less danger of this occurring with a mixture that contains a relatively small percentage of dry food and for this reason not over 30% of the dry constituent should be used at first. When the fish reach a length of four to five inches the amount of dry food may be increased, but we doubt if under ordinary conditions it is economical to use more than 40 to 50% of dry products at any time. Larger amounts usually result in excessive waste. There is no doubt that trout will do well on a considerably smaller percentage of fresh meat, but the difficulties in feeding are so great as to make the use of such mixtures impracticable.

To the inquiring mind of the practical fish culturist there immediately rises the question: "Where is the economy in feeding dry products if the cost per pound is greater than that of fresh meat?" The answer, of course, lies in the high water content of meat. Since liver contains 70% or more of water and the average dry food only about 10%, it is evident that the price of meat should be multiplied by three when compared with that of dry meals. That this method of comparison is justified is shown by the fact that our experiments with fingerling brook trout show that it requires approximately 3.7 pounds of beef liver to produce one pound of trout while it requires only 2.3 pounds of a mixture containing 70% beef liver and 30% salmon eggs to produce the same amount of fish. Experiments during the past summer show that with yearling rainbow trout 1.9 pounds of food were required to produce a pound of fish when using a mixture composed of equal parts salmon egg meal and either pig or sheep liver. On a diet of pig liver alone 5.4 pounds of food were required to produce one pound of trout. Sheep liver was more efficient, only 3.2 pounds being required to produce a pound of fish.

In view of these facts I believe we are justified in concluding that not only is it possible by the use of dry foods to reduce materially the cost of rearing trout but we can actually bring them to a catchable size in a shorter time. Furthermore, the fish will be healthier, more vigorous and brighter colored than those kept on the standard meat diets.

Discussion

MR. WEBSTER (Wisconsin): I would like to ask as to your method of feeding dry food.

DR. DAVIS: In all cases we mix the food with the ground meat—we do not feed dry food. At some places it is the practice to feed dry food one day and meat the next. We consider that rather objectionable, because you al-

ways get considerable waste when you are feeding the dry food alone. We feel that by mixing the dry food with the meat, the meat acts as a binder; the dry food absorbs the meat juices, so you are saving there. Furthermore, the mixture is much more palatable than is the dry food alone. We take the dry meal and mix it directly with the freshly ground meat, let it stand for an hour or more before feeding so that you get a more uniform mixture and it has a chance to absorb the meat juices.

MR. LORD (Vermont): These trout on the 19th of May averaged one and two-tenths ounces apiece, so they each had an equal chance to grow. On September 7 the fish on the salmon eggs averaged six ounces apiece, while the trout on the straight pig liver averaged only three ounces apiece. In the matter of dollars and cents, it takes 16c to produce a pound of trout with salmon eggs and pig liver, and with the pig liver straight it costs you 32c, so that by using cheap food you are not really saving anything.

MR. ATKINSON (Lucerne-in-Quebec): In the north it is sometimes difficult for us to get our trout up to two-inch size, which you are recommending, until, let us say, July. I have been wondering whether it would not be possible to feed your dry foods at a younger age. Buttermilk, powdered buttermilk or powdered skim milk, could be fed right from fry. Should it not be possible to obtain salmon eggs in a finer form in which they could be mixed with liver and fed from the beginning?

DR. DAVIS: Yes, that is possible. I think you will find that all you need do is run the salmon eggs through a fine sieve so that they would be fine enough to feed even the smaller fish. In fact, in experimental work we have even fed fish under two inches, but usually we find more of the dry food is wasted, so we doubt if in ordinary hatchery practice there would be much economy involved in feeding these younger fish. It is not that the fish of smaller sizes will not do well on these dry foods; it is simply a question of the difficulty of getting them to eat it.

MR. ATKINSON: Would salmon eggs be lost when mixed with liver any more than powdered buttermilk or powdered skim milk would be lost when mixed with liver?

DR. DAVIS: It won't mix as well as powdered skim milk, because that is soluble in water. It will mix as well as powdered buttermilk, but then the fish will break up the particles of meat and you will find particles of dry meal lying in the trough and much of it is wasted. With special care it can be done successfully. In ordinary practice, and not for exceptional conditions, I imagine you perhaps would find it advisable to use it for smaller fish.

MR. ROWE (Maine): I got the impression when Dr. Davis was speaking about not feeding the dry food to anything under two inches that it might be injurious to do so. I shall not attempt to make any comment, but I felt as though I had been doing something wrong. Last year I began feeding my fry at once on dehydrated salmon eggs and shrimp meal with the liver, with very good results. I mixed it as I ground it; the food was ground over probably six times to begin with so that it was thoroughly mixed. I did not see any indication of waste, and the trout certainly thrived on that food.

DR. DAVIS: No, I do not think so; mixing the way you did, you probably would have less waste, but in our experimental lots it would be difficult to do that. We just mixed it up and let it stand for some time, and the results were such that we do not feel like recommending it for ordinary hatchery procedure. But I did not mean to imply for a moment that it would be at all injurious to the fish; it is purely a matter of economy.

MR. WEBSTER: Have you ever experimented with dry sweet milk?

DR. DAVIS: Yes, we have. We put dry sweet milk and buttermilk in the same class as far as results are concerned, except there is usually more loss involved in the use of dry sweet milk because the latter is soluble in water and in feeding some of it is usually dissolved out in the water before the fish get it. For that reason we felt that buttermilk was a little better food than the sweet milk. Probably if care was taken in feeding you would not even find that that difference amounted to much. Buttermilk is insoluble, while sweet milk is soluble in water, and you have to use special care in feeding or you will lose a lot of it.

MR. WEBSTER: At the Madison hatchery we experimented successfully with dry sweet milk last year. Up to that time the fish at that station would not take enough food to grow to fingerling size in large quantities, but we found that if we mixed this milk in a very thick paste the fish took it very readily and grew very well on it. We have had a good deal of success with it at the Madison hatchery this year.

DR. DAVIS: Still, I think if you compare that with some of the other dried products such as salmon eggs you will have a surprise in store for you. Before we used the salmon eggs we were using buttermilk and dry skim milk and thought we were getting wonderful growth, but since then we have revised our opinion.

MR. WEBSTER: We commenced to use meat with it when they commenced to grow.

DR. DAVIS: With some of these other foods you will get even greater growth.

MR. FOLLETT (Michigan): Have you experimented with sweet milk curdled with rennet?

DR. DAVIS: No.

MR. FOLLETT: I wish you would try that out. One year when I found it difficult to get fresh food I secured some of this curdled milk and I had more success in raising yearlings that year than anything I had ever seen in fish culture.

DR. DAVIS: I am glad to get that.

MR. COBB (Connecticut): In comparing dry food to meat, the statement is made that the comparison should be based on a ratio of one to three or one to four. Isn't that claiming that the dry substances in these foods is all of equal value? According to that, one pound of dry salmon eggs would be equal to three pounds of liver; one pound of wheat flour would be equal to three pounds of liver, therefore one pound of wheat flour would be equal to one pound of salmon eggs. In comparing the value of one pound of dry food with four pounds of liver, it is not a true statement unless the dried

food is equal in food value to the solid product in liver, but that statement is constantly made.

DR. DAVIS: Of course that is absurd. The only thing I was trying to point out is that some dry foods are immeasurably superior to other dry foods. To put them all on an equal basis would be absurd.

MR. COBB: In comparing dry foods with the natural foods, a comparison in proportion should be made between the value of the dry food and the natural food from which it was made. One pound of dry salmon eggs would be equal to the amount of natural salmon eggs that will produce a pound of fish.

DR. DAVIS: I think you will find that one pound of salmon eggs will produce about the same amount of growth as three pounds of liver.

MR. COBB: That would not apply to all dry foods?

DR. DAVIS: No, absolutely not.

MR. COBB: Then when the statement is made that the value of dry foods should be based on one-third the value of liver, it is a misstatement, isn't it?

DR. DAVIS: It certainly is, yes.

MR. ADAMS (New York): Could you, in your experimental work and report on this, take your pound of dried salmon eggs as your base-line for the dry foods, and one of the livers, either beef or sheep or pig liver as your other base-line, and then work out a table in relation to other dry foods and other meat foods, so that we would all be in a position to answer the question to which Mr. Cobb has referred?

DR. DAVIS: Yes, that is a good suggestion; we will try to do that. I may say we have figured the growth of fish on an all dry diet, with a view to determining how much dry liver or desiccated liver would be required to produce a pound of fish. On that basis we found that liver mixed with salmon egg meal and straight beef liver come out about the same, and that on a pure dry basis it requires practically the same amount of mixture of salmon egg and beef liver to produce a pound of fish.

MR. COOK (Michigan): A few years ago I believe you discriminated against sheep liver. What are your recent findings in that connection?

DR. DAVIS: After the fish reach a length of four or five inches you can feed sheep liver or even pig liver and get equally as good results as you would with beef liver but using it in a mixture, not straight. In the experiments with yearling rainbows, however, we found that dried pig liver was very inferior to sheep liver, and yet when each was mixed with an equal amount of salmon eggs we could not find any difference at all.

MR. COOK: How extensive is the source of this dried salmon egg?

DR. DAVIS: There is plenty of it in Alaska, but I understand all that is manufactured is on Puget sound. There certainly is a large potential supply if they were to utilize it. I had intended to mention that this year at the Leetown station in West Virginia we are experimenting with haddock roe, prepared at the Birdseye Laboratory and dried by their special methods. We thought that would give equally as brilliant a color as the salmon egg meal. We had two kinds, one packed in air and one in carbon dioxide gas, and we find that that packed in the carbon dioxide gas gives a much brighter

color than that packed in air. Whether that means we have to assume a vitamin for color or not, I do not know. I do think that if salmon eggs were prepared by that method we would have an even better food than we have now.

MR. ADAMS: Have you ever carried on any experiments with alewife eggs?

DR. DAVIS: No; haddock roe is the only thing we have tried in addition to the salmon eggs. There is not enough available to be of any value commercially.

MR. FOLLETT: Is it found that the dry products are well assimilated by the fish?

DR. DAVIS: Some have claimed that with the dry products the fish assimilated it better. It takes about the same amount of straight beef liver as it does a mixture of beef liver and salmon eggs to produce a pound of fish.

MR. BIRDSEYE (Massachusetts): I am certainly not qualified to discuss the value of the dried food, but I might offer the suggestion that if you are going to feed dry foods, and if you are going to mix them with the more undried foods you might take a page from the book of the sausage manufacturer and in order to obtain cheaply a homogeneous mixing of the two ingredients use one of the regular whirling meat mixers. You could put in as many bushels, depending on the size of your unit, of the dry meal in one place as could conveniently be handled, put the unground lumps of meat in the other, simply let it whirl and then empty it from the mixer when it is sufficiently prepared. By that means you will get a perfectly homogeneous mixture very cheaply.

MR. HAYFORD (New Jersey): I am very much interested in what Mr. Birdseye has said. We have gone into this at Hackettstown on somewhat different lines. I have a paper on this subject but I may say that in the last three years, by using various combinations of food, we have reduced the cost of feeding our fish from about forty-two to thirty-one per cent of the quantity required to make a pound of fish. We feed nearly a million pounds of stuff a year. Instead of using a whirling hopper we mix it up with a shovel on the concrete floor, and it is well mixed when we get done with it.

A STUDY OF COMPARATIVE RESULTS FROM STOCKING BARREN LAKES WITH RAINBOW TROUT

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The outright ownership of an extensive but compact property with a number of lakes, representing a wide variety of conditions, offers to the Seigniory Club of Lucerne-in-Quebec excellent opportunities for studying the results of stocking under varying conditions and for obtaining comparative data on such results where the chemical, food and related conditions are reasonably well known. Although we commenced actual fish culture only in the summer of 1931, the previous summer having been spent on investigation of the property, such significant results have been obtained in the past twelve months that it seems well to prepare a progress report upon some of them.

The present paper deals with the comparative conditions and results obtained with rainbow trout (*Salmo irideus*) in two lakes. None of these lakes contained any game fish, or large competing fish such as suckers, at the time of planting, which naturally resulted in the accumulation of a large food supply. The summarized data on these three lakes previous to stocking is given in the accompanying Tables I to III.

TABLE I. PHYSICAL AND CHEMICAL CONDITIONS IN AUGUST

Lake	Surface Area, Acres	Maximum Depth, Feet	Temperatures Depth	Deg. C.	p H	Hardness ppm. $CaCO_3$
Three Point	28	35	0	22	6.9	21
			10	21	6.8	
			20	10	6.0	
			30	7	Below 6.0	
Sugar Bush	32.4	71	0	22	7.6	58
			10	21	7.6	
			20	10	7.3	
			30	5	7.0	
Green	23.5	33	0	22	7.8	85
			10	21	7.8	
			20	8	7.2	
			30	5.5	6.8	

The chemical and temperature data are from the averages of two or more readings in August of different years. Naturally a certain amount of difference is found from year to year, as well as throughout the season, but such significant differences as are shown in Table I have been sufficiently constant to justify their presentation as typical August conditions. Hardness, in midsummer, has been found to be reasonably uniform at all depths in our lakes and is here given only for the surface. The variation in hardness and in hydrogen-ion concentration is correlated with the presence or absence, along the shores of the lakes, of the so-called Grenville lime-

stone, a rock formation which ante-dates even the old gneiss or metamorphosed granite which forms the great mass of the Laurentian plateau.

TABLE II. BIOLOGICAL CONDITIONS IN AUGUST

Lake	Macroscopic Aquatic Vegetation	Minnows	Aquatic Insects	Fresh-water Shrimp
Three Point	Scarce	Abundant	Moderately Scarce	Absent
Sugar Bush	Scarce	Abundant	Abundant	Moderately Abundant
Green	Moderately Abundant	Absent	Very Abundant	Very Abundant

The data in Table II are compiled from various observations, plankton samples and stomach analyses. The macroscopic vegetation in all lakes included pipewort (*Eriocaulon articulatum*), a few yellow water lilies (*Nymphaea advena*) and pondweeds (*Potamogeton sp.*). In Green lake musk grass (*Chara sp.*), a well known calciphile, was also abundant at one end, while it also occurs in Sugar Bush lake, though less plentifully.

The minnows were approximately equal numbers of red-bellied dace (*Chrosomus erythrogaster*) and fatheads (*Pimephales promelas*), with a very few specimens of Nachtrieb's minnow (*Margariscus margarita nachtriebi*). The first two do not reach a length of more than three inches with us, while the third may grow to nearly five. All three species have small mouths and feed mainly on plankton, algae and bottom debris.

The aquatic insects noticed most prominently were midge (*Chironomus sp.*) pupae and some larvae, and mosquito larvae (*Corethra sp.*). These latter are a common plankton form in the deeper water. Less important insects included caddis-fly larvae, dragonfly and mayfly nymphs, water-boatmen and similar forms.

The fresh-water shrimp referred to was this Society's old friend, *Gammarus limnaeus*. As is general with this species, it was associated with the harder waters. However, instead of occurring in cold streams among vegetation, as is generally recorded, it was to be found as a plankton form in the region of the thermocline. In Green lake, it was so abundant, around the twenty-foot level, as to literally clog the gill nets in 1930 and 1931. It should be mentioned that the smaller shrimp, *Hyalella knickerbockeri*, was found in all three lakes among vegetation in shallow water but that it did not form any appreciable part of the trout diet, at least in July and August.

The following plantings of counted rainbow trout fingerlings, between two and one-half and three inches in length, were made in 1931:

Three Point	August 31	2,000
Sugar Bush	September 2 and 3	2,970
Green	September 1	2,000

The results obtained from these plantings are shown in Table III.

TABLE III. RAINBOW TROUT CAUGHT ONE YEAR AFTER PLANTING FINGERLINGS

Lake	Number of Fish Examined	Average Length Inches	Average Depth Inches	Average Weight Ounces	Estimated Relative Survival
Three Point	3	9½	2½	6½	10
Sugar Bush	4	12	3	16	20
Green	14	13¼	3½	20	100

The fish recorded in Table III were all taken with gill nets, a wide range, of from one and one-quarter to four inch stretched mesh, being used to avoid selective catches. The majority of the fish were taken in two and one-half inch nets. The only column that calls for explanation is the last. This is based on the number of fish taken to the area of gill net used and is purely a rough estimate of the relative survival. What the actual survival is in any lake is naturally not known, but a four foot deep sixty foot net in Green lake took sixteen fish over night in July and the actual survival is evidently high. In the other two lakes the survival appears much lower, especially in three Point lake, although the very much smaller catches may be associated in part with differences in feeding habits.

The results obtained in Green lake are so considerably ahead of anything recorded in the east of this continent that a more detailed analysis of the stomach contents is given in Table IV. Of fourteen fish taken on the night of September 2nd, one contained no food. The rough analyses of the stomach contents of the other fish are shown in Table IV. All fish taken were in extremely fat condition and showed indications that they will spawn next spring, that is, when two years old.

TABLE IV. STOMACH ANALYSES OF RAINBOW TROUT FROM GREEN LAKE, SEPT. 2, 1932. ALL DATA ESTIMATED PERCENTAGE VOLUME

Weight of Fish Ounces	Gammarus limnaeus	Chironomid Larvae and Pupae	Corethra Larvae	Miscellaneous Aquatic Insects
26	50	—	—	20
26	50	—	—	50
23	60	—	40	—
21	—	100	—	—
21	75	—	25	—
20	50	—	—	50
20	20	80	—	—
20	5	95	—	—
18	30	70	—	—
18	60	—	—	40
17	10	40	50	—
16	20	80	—	—
16	20	—	—	80
Total 262	480	465	115	240
Average 20	37	36	9	18

The first point to be noted is that phenomenal growth, as compared with that usually obtained in the eastern half of this continent, was obtained in two lakes and that what may be considered excellent growth was obtained in the third (Three Point). Since no large competing or enemy fish were present in the lakes at the time the planting was made this is only natural, since the food supply was undoubtedly abnormally plentiful. Such growth, however, does make one realize what a large scope there is for research work towards finding more suitable food for trout where reared under artificial conditions.

The second consideration is the apparent wide variation in the relative survival. All plantings were made in identical fashion at suitable spots around the shores of the lakes, since no creeks flow into these lakes. The air and water temperature at the time of planting were abnormally high for the time of year, but the survival in Green lake suggests that these were not important factors in causing any loss that may have occurred. The growth of all fish taken is so satisfactory that it seems that any considerable mortality must have occurred fairly soon after planting, if it is connected with food conditions. Immediately after planting the fingerlings were observed to be chasing the very young minnows, but it is probable that later the young trout went to somewhat deeper waters, where the minnows probably are not so abundant. Even at that there should have been a sufficient supply of insects and other forms of life to supply the needs of these fish.

Until a further study has been made it seems well to consider, however, that the survival from even fingerlings plantings in lakes and even where no predaceous fish are present, may not be as high as one might expect, except where the food conditions are exceptionally favorable. This is a question which merits detailed investigation, similar to that which has recently been conducted on trout streams in the Maritime Provinces.

In conclusion it should be stated that no one is more conscious than the author of the mass of data missing from this paper which would be required to make it complete. Since the writer's duties are, however, primarily economic rather than investigational, the latter phase is necessarily very limited and, in presenting such an incomplete study, he relies on the charity of his co-workers to accept it for what it is worth.

Discussion

MR. ATKINSON: It would be of distinct advantage to those who are interested in such studies as these, if some state or department could set aside an experimental area which they own outright, perhaps a couple of hundred square miles, in which work could be carried on in connection with stocking, the removal of fish, and general field work of that type, without the necessity of producing fishing. My activities in this direction are limited

in that I have to produce fishing. My desire with respect to these lakes would be, about a year from now, to clean them out as completely as possible. I believe that before we know exactly where we are going in our stocking we need experimental areas owned and controlled by the government which are closed to all fishing and used purely for experimental purposes.

DR. EMMELINE MOORE: Have you any reason to advance for the lakes being barren?

MR. ATKINSON: Yes. All these lakes are situated at comparatively high elevations for our district. The level of the Ottawa river at Lucerne is 130 feet; the sea is known to have gone to around 600 or perhaps 700 feet, whereas these lakes are up around 900 feet or higher. In each of these three lakes there are falls on the outlets which prevent any upward migration of fish. How the minnows got into the two lakes I do not know; whether they were there at the time of the raising of the water, or whether they were distributed by birds, as has been suggested, I am not prepared to say.

MR. MARKUS: What is the name of the fathead minnow?

MR. ATKINSON: Pimephales promelas.

MR. ODELL (New York): I was wondering whether rainbow trout were selected for planting in lakes which had no inlets.

MR. ATKINSON: Most of our country is speckled trout country. We wished to secure earlier results from planting, which we have done, and a variety of fishing; and also to improve the fly fishing throughout the summer. My experience has been that rainbow trout will take the fly for a longer period than speckled trout in lakes. Most of the lakes in the district have no appreciable inlets, and the lakes selected were chosen on account of the absence of speckled trout.

THE EXTENT TO WHICH TEMPERATURE CHANGES INFLUENCE FOOD CONSUMPTION IN LARGE-MOUTH BASS (*HURO FLORIDANA*)

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Introduction. The question often arises among bass culturists—how much food is required by brood bass during the winter months when it is difficult to obtain? This together with suggestions from Dr. H. S. Davis have prompted the writer to conduct the experiments here described. They were carried on at the U. S. Bureau of Fisheries Laboratory at Fairport, Iowa, during the winter of 1931-32. I want to take this opportunity to thank Dr. A. H. Wiebe for his assistance in making available the material used.

Laboratory Equipment. Glass aquaria were used for that part of the experiment pertaining to the rate of digestion in relation to temperature with the exception of the four degree experiment, which was conducted in a concrete tank. The dimensions of the aquaria were forty-seven inches long, sixteen and one-quarter inches wide and eighteen inches deep. Each aquarium was divided into two equal compartments by a screen partition. The concrete tank was divided into four compartments, each having a capacity equal to one-half of one aquarium.

Well water was used throughout the experiment and was kept at a depth of sixteen inches in both aquaria and concrete tank. The water temperatures remained fairly constant, never varying more than one-half degree from the desired reading, with the exception of the four degree experiment, which varied between three and five degrees. This, however, remained at four degrees the greater part of the time.

The oxygen content of the water was kept between seven and twelve parts per million. This was achieved in the warm water, with no difficulty, by bubbling pure oxygen through the water. Pure oxygen was employed where artificial aeration had to be used throughout the experiment. The ten degree aquaria and the concrete tank in the Tank House, whose temperatures were regulated by running water, kept up their oxygen content without artificial aeration by the splashing of the incoming water.

In performing the continuous feeding experiments four metal tanks were used to hold the bass. These tanks were twenty inches wide, fourteen inches deep and two of which were sixteen feet long and the remaining two were twelve feet long. Each of the four tanks was divided into four foot equal compartments.

Method of Approach. The problem was approached in two ways.

The first was to determine how long it would take a bass to digest a four or five gram minnow at a given temperature. The question arose, how to determine when the minnow was completely digested. After experimenting for some time with various methods the problem was finally solved by injecting a solution of hydrochloric acid and arsenous acid into the stomach of the bass. This procedure caused the entire stomach contents to be thrown out within a few minutes in the warm waters and a somewhat longer time in the colder water. The details of this method will be described later in this paper.

The experiment was conducted at six different temperatures. Four bass were used for each temperature experiment, two large and two small ones. The six different temperatures used were four, ten, sixteen, twenty-two, twenty-eight and thirty-four degrees C. Careful records are kept of the temperatures in the rearing and holding ponds at Fairport during the entire year. It was found by checking over the winter records of the stock ponds that the temperature remained about four degrees C. during a greater part of the time. The maximum temperature of thirty-four degrees C. was chosen because the ponds reach that temperature during the summer. The six degree intervals between the extremes four and thirty-four were chosen for convenience. It was found that water at ten, sixteen and twenty-two degrees C. could be had in the laboratory without any additional heating or cooling device. For that reason the six degree intervals were chosen and they proved to work out in very satisfactory manner.

The second method of approach was to keep a continuous supply of minnows exposed to the bass and determine the number and weight of food taken at the various temperatures. At the beginning of the experiment the bass were weighed and measured. Two large and two small bass were used for each experiment, and each bass was kept in a separate compartment. Minnows were counted, weighed and put in with each bass. As soon as the last minnow was taken more were added. Every thirty days the bass were weighed and measured. This was done for three consecutive thirty-day periods.

Source of Material. During September and October the fingerling bass were removed from the Fairport ponds for distribution. Some of them had grown beyond the fingerling stage and were kept for future brood stock and experimental purposes. It was this supply that furnished the bass for this experiment. They varied in size from eleven to twenty-two cm. standard length, which is the basis for all measurements given in this paper.

Method of Procedure. As previously stated, four bass were used for each of the six different temperature experiments. Two groups of different size were used for each observation. The small bass varied from 110 to 152 mm. in length while the larger ones varied from 180 to 220 mm. The individual weights and measurements are

shown in Tables 1 to 6 inclusive. Two aquaria were used for each experiment, and those aerated artificially were arranged end to end with the oxygen tank between them. A large and small bass were placed in each aquarium with a screen partition separating the two. Each aquarium was assigned a letter of the alphabet and each compartment a number. The large bass were always placed in compartment number 1 and the small bass in compartment number 2. All bass used for experimental purposes were kept in the basement Live Room where the temperature of the water was sixteen degrees C. In preparing the twenty-two, twenty-eight and thirty-four degree C. aquaria all were started at sixteen degrees C. and the temperature raised slowly. After the temperature had reached the desired reading the bass were kept at that temperature for a week, feeding them all the while, that they might become fully acclimated to the higher temperature before actual experimentation began. The same method was used for the lower temperatures with the exception that feeding was not practiced while they were being acclimated. It was found that bass did not feed readily at ten degrees C. and at four degrees none of them ever took food voluntarily.

After making some preliminary feeding experiments it was soon found that it was highly desirable to have food of uniform size to carry on that part of the experiment. In making the preliminary observations golden shiners (*Notemigonus crysoleucas*) were used, but it was difficult to go to the field and collect them in sufficient quantity to permit a selection of uniformly sized individuals. Blunt-nosed minnows (*Hyborhynchus notatus*) were then substituted. These minnows were found in such numbers at Lyndon, Illinois, that it was easy to select individuals of uniform size. The larger ones readily fell into two groups, the four and five gram individuals. The five gram minnows were easily taken by the larger bass. The four gram minnows, although a little large, were nevertheless eaten by the smaller bass.

In determining the length of time required for the bass to digest a minnow it was necessary to know the time the food was taken and the time when digestion was completed. In the beginning of each of the experiments one five-gram blunt-nosed minnow was put in the compartment with each of the large bass and a four-gram minnow with each of the small bass. The time was recorded when each minnow was taken. In the 22, 28 and 34 degree water the bass took the minnows as soon as they hit the water. They were never given any food for at least twenty-four hours before the experiment began. This was done to make sure that the stomach of the bass was empty at the beginning of each feeding observation.

The swallowed minnow was allowed to undergo the process of digestion for a definite period of time, and then the bass was made to throw out the undigested part through the following procedure: 500 mg. of arsenous acid and 0.25 ml. of concentrated hydrochloric acid were added to distilled water to make a 500 ml. solution. The

solution was injected into the stomach of the bass through a stomach tube. The bass was placed between the folds of a wet towel, 2 ml. of the arsenous solution was injected into the stomach of the larger bass and 1.5 ml. into the smaller one. The bass was then returned to the aquarium. The stomach contents were soon ejected, and then collected from the bottom of the aquarium. The undigested remains were weighed and the amount digested was determined by subtracting the weight of that ejected from the weight of the original minnow. The arsenous acid solution did not seem to affect the bass otherwise, for within a few hours they were ready to take more food. After a period of forty-eight hours had elapsed the experiment was repeated with the same bass but with the period of digestion lengthened, until finally the bass was unable to throw out any undigested material, which indicated that digestion was complete. To prove that this was the case one of each of the large and small bass for each temperature experiment was killed and its stomach examined. In no instance was there any undigested food found.

The amount of food digested by the bass at the various intervals of time and finally when digestion was completed in the 22, 28 and 34 degree C. water is shown in Tables 4, 5 and 6.

The procedure with the bass in the 4, 10 and 16 degree C. water was the same as in the 22, 28 and 34 degree water, with the exception of the manner of feeding. The small bass in the sixteen degree water never failed to take their food voluntarily. The large bass also fed voluntarily, but it often required hours before they did so. They seemed to enjoy making preliminary short strikes at the minnows. In order to save time the bass was caught and placed between the folds of a wet towel and forced feeding with a pair of forceps was attempted. This was highly successful and when the process was repeated on the other bass it was found that they could be made to take their food any time desired providing there was no food in the stomach. If the bass had any quantity of food in its stomach it would not take additional food by this method. Since the bass in the four and ten degree water would not feed voluntarily they were given minnows at the desired time by the hand method.

The period of time required for the bass to complete digestion of minnows in four, ten and sixteen degree water is shown in Tables 1, 2 and 3.

Table 8 indicates the amount of food taken by the bass for each of the thirty-day periods also the loss or gain in weight. In the last column of Table 8 the loss and gain in weight and the gain in length is presented for the ninety-day period.

Discussion. From the results obtained in this series of experiments it seems quite evident that bass take little or no food during the winter months when the temperature of the water remains around four degrees C. This is especially true of the larger bass used in

this experiment. The small bass took food in much colder water than did the large bass as shown in tank C, compartments 1 to 6, inclusive, in Table 8. In tank B, whose temperature ranged from twelve to fourteen degrees C., the small bass took much more food in proportion to size of fish than the large bass. This was not so evident in tank A, where the temperature ranged from sixteen to twenty degrees C. In this case, A4 (Table 8) made the largest gain in length and weight and took the greatest amount of food. It may be of interest to note that this bass took as many as eighteen minnows at a single feed that weighed twenty-seven grams. Another interesting observation noted in conducting this series of experiments was that when a bass swallows a scaled fish the greater part of the scales are thrown out again through the mouth and gill openings.

The greatest variation in the rate of digestion between the large and small bass as far as time was concerned occurred at sixteen degrees C. as shown in graph number 1. At this temperature the large bass digested their food 2.62 times faster in proportion to the other temperatures. It is interesting to note that at four degrees C. both large and small individuals digested their food in the same length of time. A variation then began, as indicated by the graph and tables, until twenty-two degrees was reached, when the variation became less marked. Hathaway, 1927: 429, states, "Incidentally, it was noticed that the smaller fishes ate more in proportion to their body weight than did the larger individuals of the same species." Hathaway used temperatures ten and twenty degrees C. to carry on his feeding experiments. The results of our experiments as shown in Table 7, confirm Hathaway's findings. But, as indicated in this table, the small bass used much more food than the large bass at the lower and higher temperatures in proportion to the size of the fish than they did at ten and twenty-two degrees C. In Table 7, the amount of food consumed per hour, per gram body weight, was determined for bass of different sizes and at the various temperatures. For example, one gram of the 205 mm. bass at four degrees C. used 0.0000694 gram of food in metabolism for one hour, while one gram of the 122 mm. bass used 0.0002777 gram of food in one hour at the same temperature, which shows that the rate of metabolism is much higher in the smaller bass at the same temperature.

SUMMARY

1. The rate of metabolism in bass is very low at four degrees C. and increases very rapidly as the temperature increases up to twenty-two degrees C. After that temperature is reached the rate of increase diminishes.

2. None of the large bass took food voluntarily in water temperatures

below ten degrees C. during the ninety days the experiment was in progress.

3. The rate of metabolism is much greater in small bass than large bass, especially at the lower and higher temperatures.

4. Small bass feed in colder water than large bass.

5. Bass may be made to throw out undigested food at any desired time by injecting a solution of arsenous acid and hydrochloric acid into the stomach.

6. Bass can be made to take minnows at any time desired by placing them between the folds of a wet towel and inserting the minnow into its mouth.

7. Bass do not seem to take food readily unless the stomach is empty.

LITERATURE CITED

Hathaway, Edward S. 1927. The Relation of Temperature to the Quantity of Food Consumed by Fishes. Ecology 8: 428-434.

TABLE 1.—Showing rate of digestion of the G and H series of bass feeding experiments conducted in water with a temperature of 4 degrees Centigrade. The food was 4 and 5-gram Hyborhynchus notatus. The 5-gram minnows were fed to the G1 and H1 bass and the 4-gram minnows to the G2 and H2 bass.

Experiment number of bass	Length of bass in mm.	Weight of bass in grams	Number of grams of food digested in 48 hours	120 hours	240 hours	360 hours
G1	190	170	0.2	3	4.25	5
G2	126	54	0	1.5	3	4
H1	205	200	0.2	3.75	4.75	4.9
H2	122	40	0	1.5	3	4

TABLE 2.—Showing the rate of digestion of the E and F series of bass conducted in water with a temperature of 10 degrees Centigrade. The food used was 5 and 4-gram Hyborhynchus notatus. The 5-gram minnows were fed to the E1 and F1 bass and the 4-gram minnows were fed to the E2 and F2 bass.

Experiment number of bass	Length of bass in mm.	Weight of bass in grams	Number of grams of food digested in 10 hours	24 hours	48 hours	72 hours	92 hours	168 hours
E1	195	158	0	1.5	2.5	4.5	5	
E2	129	39	0	1	1.5	2.5	3.25	4
F1	180	121	0	1.5	2.5	4	5	
F2	122	33	0	0.5	1.5	2.5	3	4

TABLE 3.—Showing the rate of digestion of the C and D series of bass conducted in water with a temperature of 16 degrees Centigrade. The food used was 5 and 4-gram Hyborhynchus notatus. The 5-gram minnows were fed to the C1 and D1 bass and the 4-gram minnows were fed to the C2 and D2 bass.

Experiment number of bass	Length of bass in mm.	Weight of bass in grams	Numbers of grams of food digested in 4 hrs.	6 hrs.	10 hrs.	14 hrs.	18 hrs.	24 hrs.	32 hrs.	48 hrs.	52 hrs.	84 hrs.
C1	200	160	0	0.25	0.75	1.5	2	4.75	5			
C2	119	30	0	0.25	0.25	1	1	1.5		3.75	3.75	4
D1	180	123	0	0.25	0.75	1	1.5	3	5			
D2	129	39	0	0.25	0.5	1	1	2		3	3.5	4

TABLE 4.—Showing the rate of digestion of the A and B series of bass conducted in water with a temperature of 22 degrees Centigrade. The food used was 5 and 4-gram Hyborhynchus notatus. The 5-gram minnows were fed to the A1 and B1 bass and the 4-gram minnows were fed to the A2 and B2 bass.

Experiment number of bass	Length of bass in mm.	Weight of bass in grams	Number of grams of food digested in 4 hours	10 hours	12 hours	14 hours	16 hours	18 hours	22 hours
A1	205	175	0.25	3.5	4.5	4.8	5		
A2	130	42	0	1.5	2.25	3	3	3.5	4
B1	205	177	0.25	3.5	4.75	5			
B2	130	47	0	2	2.5	3	3	3.5	4

TABLE 5.—Showing rate of digestion of the I and J series of the bass conducted in water with a temperature of 28 degrees Centigrade. The food used was 5 and 4-gram Hyborhynchus notatus. The 5-gram minnows were fed to the I1 and J1 bass, and the 4-gram minnows were fed to the I2 and J2 bass.

Experiment number of bass	Length of bass in mm.	Weight of bass in grams	Number of grams of food digested in 4 hours	10 hours	12 hours	16 hours
I1	190	140	2.5	4.8	5	
I2	110	27	1	3.25	3.25	4
J1	185	130	2.5	4	5	
J2	126	40	2	3	3	4

TABLE 6.—Showing rate of digestion of the K and L series of the bass conducted in water with a temperature of 34 degrees Centigrade. The food used was 4 and 5-gram Hyborhynchus notatus. The 5-gram minnows were fed to the K1 and L1 bass and the 4-gram minnows were fed to the K2 and L2 bass.

Experiment number of bass	Length of bass in mm.	Weight of bass in grams	Number of grams of food digested in 6 hours	10 hours	12 hours
K1	220	153	4.5	5	
K2	147	46	3	3.25	4
L1	215	140	4.5	5	
L2	152	54	3.00	3.75	4

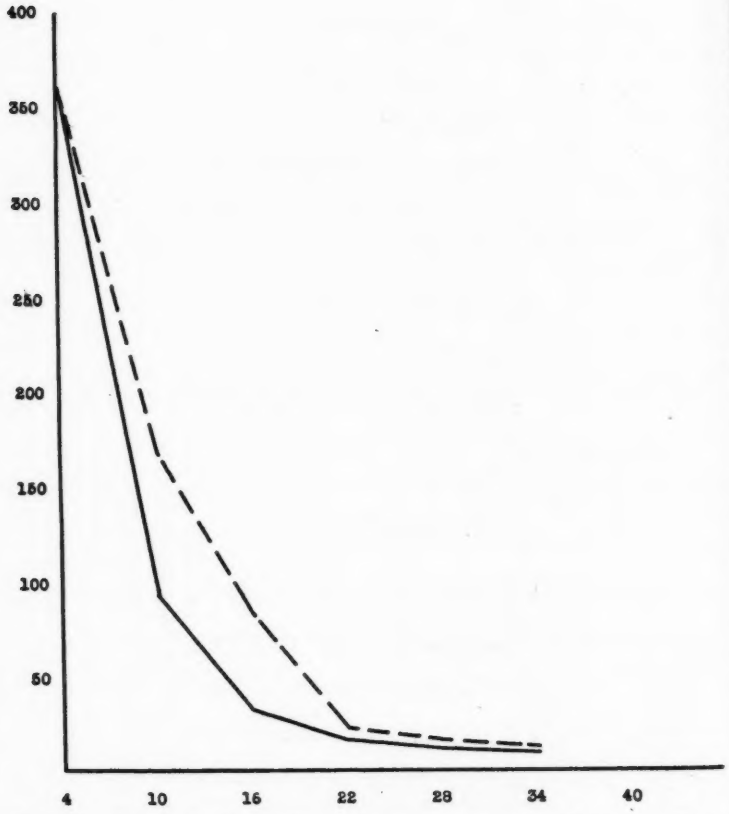
TABLE 7—Showing the amount of food used in metabolism per gram of bass at the given temperature for one hour.

Experiment number of bass	Length of bass in mm.	Weight of bass in grams	Hours required for digestion	Weight of minnow in grams	Temperature in degrees Centigrade	Rate of digestion per bass gram in 1 hour
G1	190	170	360	5	4	0.0000816
G2	126	54	360	4	4	0.0002057
H1	205	200	360	5	4	0.0000694
H2	122	40	360	4	4	0.0002777
E1	195	158	92	5	10	0.0003439
E2	129	39	168	4	10	0.0006041
F1	180	121	92	5	10	0.0004491
F2	122	33	168	4	10	0.0007214
C1	200	160	32	5	16	0.0009765
C2	119	30	84	4	16	0.0015869
D1	180	123	32	5	16	0.0012703
D2	129	39	84	4	16	0.0012202
A1	205	175	16	5	22	0.0017856
A2	130	42	22	4	22	0.0043290
B1	205	177	14	5	22	0.0020178
B2	130	47	22	4	22	0.0038682
I1	190	140	12	5	28	0.0029762
I2	110	27	16	4	28	0.0092592
J1	185	130	12	5	28	0.0032050
J2	126	40	16	4	28	0.0062500
K1	220	153	10	5	34	0.0032679
K2	147	46	12	4	34	0.0072464
L1	215	140	10	5	34	0.0035714
L2	152	54	12	4	34	0.0061728

TABLE 8.

Experiment number	Length and weight of bass at beginning of experiment, December 15.		Temperature range in degrees Centigrade, Dec. 15 to Jan. 15.	Amount of food taken and loss or gain in weight of bass from December 15 to January 15, 1932.				Temperature range in degrees Centigrade, Jan. 15 to Feb. 15.	Amount of food taken and loss or gain in weight of bass from January 15 to February 15, 1932.				Temperature range in degrees Centigrade, Feb. 15 to March 15.	Amount of food taken and loss or gain in weight of bass from February 15 to March 15, 1932.				Loss or gain in length or weight during the three months.	
	Length of bass in mm.	Weight of bass in grams		Number of minnows taken	Weight of minnows taken	Weight of bass Jan. 15—grams	Amt. gain during mo., grams		Number of minnows taken	Weight of minnows taken	Weight of bass Feb. 15—grams	Amt. gain during mo., grams		Number of minnows taken	Weight of minnows taken	Weight of bass Mar. 15—grams	Amt. gain during mo., grams	Length of bass March 15	Gain in length in mm.	Gain in weight in grams
A1	115	25	17-20	34	54	33	8	16-20	54	80	41	8	16-20	40	58	57	16	136	21	32
A2	115	28	17-20	45	64	43	15	16-20	63	140	64	21	16-20	62	94	90	26	154	39	62
A3	185	149	17-20	63	118	151	2	16-20	53	121	185	34	16-20	51	111	192	7	202	17	43
A4	195	166	17-20	53	107	190	24	16-20	24	38	230	40	16-20	101	193	297	67	225	30	131
B1	112	26	12-14	28	42	34	8	12-14	18	30	37	3	12-14	11	21	37	0	120	8	11
B2	118	30	12-14	30	37	37	7	12-14	30	44	44	7	12-14	15	29	44	0	128	10	14
B3	180	116	12-14	29	59	122	6	12-14	22	51	134	12	12-14	25	64	135	1	185	5	19
B4	190	144	12-14	32	51	150	6	12-14	14	22	154	4	12-14	25	60	162	8	190	0	18
C1	115	30	5- 9	21	29	30	0	1- 8	0	0	30	0	5- 9	2	5	30	0	115	0	0
C2	187	142	5- 9	6	12	138	4*	1- 8	0	0	135	3*	5- 9	0	0	135	0	187	0	7**
C3	195	164	5- 9	6	15	152	12*	1- 8	0	0	150	2*	5- 9	0	0	150	0	195	0	14**
C4	109	23	5- 9	10	15	25	2	1- 8	0	0	25	0	5- 9	4	9	26	0	109	0	3
C5	125	39	5- 9	14	21	41	2	1- 8	0	0	41	0	5- 9	4	8	41	0	125	0	3
C6	193	157	5- 9	16	21	126	21*	1- 8	0	0	123	3*	Died							

*Indicates a loss in weight during the month from December 15, 1931, to January 15, 1932.
**Indicates a loss in weight during the time the experiment was in progress, which was from December 15, 1931, to March 15, 1932.



Graph No. 1.—The horizontal line indicates the temperature in degrees Centigrade at which the rate of metabolism experiments were performed. The vertical column indicates the number of hours required for the bass to complete digestion. The broken line indicates the rate of digestion of the small bass, while the solid line indicates the rate of digestion of the large bass.

THE EARLY GROWTH OF SALMON PARR IN CANADIAN HATCHERIES

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Except from the standpoint of successful hatchery production, the early life of the Atlantic salmon has received less attention than its adult life. This paper deals with the conditions which influence the existence of the salmon from the time of the fertilization of the egg to sixteen weeks after hatching. Owing to the difficulty of collecting adequate material under natural conditions in the rivers, it has been necessary to use salmon which were reared at hatcheries. In order to minimize the influence of artificial culture, young salmon of different ages were obtained through the cooperation of the Canadian Department of Fisheries from eight hatcheries. A comparison of these hatcheries during the several stages in the early life of the salmon pass has disclosed certain facts of interest to the fish culturist.

In the comparison of these hatcheries the rapidity of growth is the only criterion for determining their relative success. However, the true value of a hatchery is not measured by the rapidity of growth but also by the low mortality and vigor of the product. Since a hatchery which produces a rapid growth may become during the summer months, because of high water temperature, of little practical value, comparisons from the standpoint of growth alone must be judged in the proper perspective of the factors which make a successful hatchery.

METHODS OF WORK

Salmon were obtained from eight hatcheries, which are given the Roman numerals I to VIII. The eggs were obtained from seven sources, details concerning which are given in Table 1, and are indicated by the letters A to G. In one instance they were distributed among four hatcheries and in two instances among two.

TABLE I. SOURCES OF SALMON EGGS

Parent Salmon				
River	Place of Capture	Date of Capture	Run	Hatchery
A	River	October 1 to November 19	Fall	I
B	Bay	May 25 to July 1	Spring	II
C	Mouth of river	May 29 to June 30	Spring	II, III
D	River	September 20 to October 19	Fall	IV, V, VI, VII
E	River	September 19 to November 4	Fall	V
F	River	October 21 to November 23	Fall	VI, VIII
G	Mouth of river	May 6 to June 5	Spring	VII

Starting with the first day of hatching, ten salmon were preserved in formaldehyde each week until the salmon were liberated from the hatchery. As far as possible a fair sampling was carried out by the superintendents. The individual salmon, which were measured, weighed, and received scale examination, furnish the basis for this report. The small number of specimens per week tended to produce irregularities in the growth curves, particularly during the advanced weeks of hatchery life when there was considerable variation in the size. The irregularities were eliminated by the ordinary methods of treating such material, and only the smoothed growth curves are presented.

The food and methods of feeding were the same at the different hatcheries. The method of holding, though probably uniform, at least through the early stages, the flow of water, and the chemical composition of the water were not obtained. The differences in the hatcheries were chiefly the temperature of the water and the general environment, which can only be analyzed by a detailed study of the actual conditions operating in each hatchery. Since we are dealing with the possibility of unknown variables, our conclusions must be correspondingly qualified.

Incubation Period

Table 2 gives the details in regard to the time of fertilization, date of hatching, days of incubation, and average temperature during the incubation period for the various hatcheries and eggs. No allowances is made except as regards temperature for the brief time that the eggs were held at the original source before their transfer to the hatcheries.

Several factors complicate the general conditions governing the duration of the incubation period and it is impossible to assign the leading role to any one. However, some idea of the influence of certain conditions can be determined by considering them separately.

TABLE 2. INCUBATION PERIOD

Hatchery	River	Date Eggs Fertilized	Date of Hatching	Days' Incubation	Average Temperature During Incubation (Fahrenheit)
I	A	November 15	March 15	120	36.4
II	B	October 30	May 2	184	35.5
	C	November 3	May 2	180	35.5
III	C	November 3	April 20	168	34.6
IV	D	October 24	May 4	192	34.3
V	D	October 24	April 14	172	36.1
	A	November 15	April 11	147	35.5
	E	November 20	April 19	150	35.2
VI	D	October 24	April 26	184	38.1
	F	November 14	April 26	163	37.5
VII	D	October 24	April 25	183	41.4
	G	November 4	March 21	137	40.5
VIII	F	November 14	April 23	160	35.2

Hatchery: The influence of the environment of a hatchery upon the duration of the incubation period is demonstrated by the following

instances. The incubation period of River D eggs at four hatcheries was: Hatchery IV, 192 days; Hatchery VI, 184 days; Hatchery VII, 183 days; Hatchery V, 172 days. River C eggs required 180 days at Hatchery II and 163 days at Hatchery III. River A eggs required 147 days at Hatchery V and 120 days at Hatchery I.

Temperature: Contrary to expectations, temperature of the water between 34 and 41° F. is not a prominent factor in determining the length of the incubation period, although it is possible that variations at certain crucial periods may exert a controlling influence. However, temperatures above 41° F. produce a marked decrease in the time of incubation. At a hatchery not included in this series, eggs from the same source but held in different waters hatched at 42.0° F. in 88 days and at 33.0° F. in 191 days. There is little difference in the average temperature of the seven hatcheries during this period, and there is no apparent correlation between the temperature and time of incubation. The following data indicate no relation between the average temperature within the 34 to 41° F. range during incubation and the length of the incubation period. River D eggs required 183 days at Hatchery VII at 41.4° F., 184 days at Hatchery II at 38.1° F., 172 days at Hatchery V at 36.1°F., and 192 days at Hatchery IV at 34.6° F. Hatchery III, with a temperature of 34.6° F. hatched River C eggs in 168 days, whereas Hatchery II with a temperature of 35.5° F. required 180 days for the same eggs. The opposite was true for River A eggs, which hatched in 147 days at Hatchery V with a temperature of 35.5° F. and in 120 days at Hatchery I with a temperature of 36.4° F. River F eggs hatched at Hatchery VIII in 160 days at 35.2° F. and at Hatchery VI in 163 days at 37.5° F.

Source: There is evidence to indicate that heredity (the source of the eggs) exerts some influence upon the length of the incubation period. River D eggs, which have a long incubation period, are reasonably consistent as to the length of the period irrespective of the hatchery. River F eggs are consistent for a shorter period of incubation at two hatcheries. River A eggs, with a very short incubation period, and River C eggs, with a long period, are less consistent, but not absolutely contradictory. Table 3 demonstrates a certain uniformity for the river species.

TABLE 3. SOURCE OF EGGS AND LENGTH OF INCUBATION PERIOD

Source	Hatchery	Incubation Period in Days	
		Own River	Other Rivers
River D	IV	192	—
	V	172	147-150
	VI	184	163
	VII	183	137
River F	VIII	160	—
	VI	163	184
River A	I	120	—
	V	147	150-172
River C	III	168	—
	II	180	184

Spring- vs. Fall-Run Salmon: The Atlantic salmon spawns during the last of October in the rivers of eastern Canada. The salmon first enter the rivers during the last of May and continue to run until October. Certain rivers have the greater part of their run in the spring (June); others have only a fall run (September and October); still others have a mixture of spring-and fall-run salmon. It has been advocated that spring-run salmon breed spring-run offspring and fall-run salmon fall-run offspring. This question is important from a hatchery standpoint, since only spring-run salmon are of value for commercial and sport fishing.

Since three sources of salmon eggs were from spring-run salmon and four from fall-run, a comparison of the incubation periods is of interest. The eggs of Rivers B, C and G were from spring-run salmon and required 137, 184, and 168-180 days' incubation. The eggs from Rivers A, D, E and F were from fall-run salmon and required 120-147, 172-192, 150, and 160-163 days, respectively. It is evident that the incubation period is not affected by the time of run of the parent salmon.

Size of Egg: In general the size of the egg depends upon the size of the parent salmon, the larger specimens producing the larger egg. Also, the size of the egg varies with the salmon of the different rivers. The material used in this study permits its division into two classes, large and small eggs. There is no relationship between the size of the egg and the length of the incubation period. Two rivers, B and F, produced large eggs with an incubation period of 184 and 160-163 days. Four rivers, A, D, E, and G, produced small eggs with incubation periods of 120-147, 172-192, 150, and 137 days. River C eggs were both large and small and had 168 and 180 days' incubation, respectively.

Time of Fertilization: Davis* has shown that in brook trout heredity influences the time of spawning. Since it appears from our data that the length of incubation of the Atlantic salmon egg is influenced by heredity, it is possible that the time of fertilization may affect the incubation period.

The time of spawning varies under natural conditions with the season and with the individual river. The difference in the time of ripening of the salmon eggs of seven river varieties in 1931 varied from October 19 to November 11 and the average time from October 24 to November 20. The time of spawning has no apparent relation to the length of the incubation period. If anything it suggests a compensation in the form of a shorter incubation for the late spawning salmon.

Date of Hatching: Hatchery conditions rather than the source of the eggs determine the date of hatching. River D eggs at four hatcheries ranged from April 14 to May 4, River A eggs at two

*Davis, H. S. Transactions of the American Fisheries Society, 1931, p. 43.

hatcheries from March 15 to April 11, and River F eggs at two hatcheries from April 23 to April 26.

The time of hatching is quite consistent at the several hatcheries. Hatchery V with eggs from three sources ranged from April 11 to April 19. Hatchery II and Hatchery VI with eggs from two sources had the same hatching day, May 2 and April 26. The only marked exception was Hatchery VII, where the two lots of eggs were five weeks apart, March 21 and April 25. The earliest date of hatching was at Hatchery I on March 15 and the latest at Hatchery IV on May 4.

The date of hatching seems to be influenced by the location of the hatchery. It is noteworthy that the earliest hatching took place in the mildest region, Prince Edward island, on March 15; in the hatcheries in Nova Scotia and southern New Brunswick between April 11 and April 26; in the more northerly hatcheries between May 2 and May 4.

The association of the time of hatching with the location of the hatchery suggests that the temperature of the water at the end of the incubation period may determine the date of hatching. A comparison of the hatcheries as to the temperature of the water at the time of hatching shows that the early hatcheries have only a slightly lower water temperature at that date than the late hatcheries. Five hatcheries have at that time a water temperature of between 35° F. and 38° F., and three between 41° F. and 43° F., giving an average of 38° F. Evidently hatching can take place at 35° F. and may not take place until 43° F.

Yolk Sac Period

The yolk sac period, in which the salmon fry obtains its nourishment by absorption from the yolk sac previous to feeding, presents several features of interest to fish culturists.

TABLE 4. YOLK SAC PERIOD

Hatchery	River	Date of Hatching	End of Yolk Sac Period	Days' Duration, Yolk Sac Period	Temperature Start	Temperature End	Temperature Average
I	A	March 15	May 19	65	36	54	41.2
II	B	May 2	July 6	63	36	45	41.8
	C	May 2	June 30	59	36	46	41.2
III	C	April 20	May 23	33	37	56	47.2
IV	D	May 4	June 3	30	39	56	48.6
V	D	April 14	June 3	50	37	49	41.9
	A	April 11	June 3	53	36	49	41.9
	E	April 19	June 7	49	38	50	42.8
VI	D	April 26	May 26	30	42	54	48.8
	F	April 26	May 29	32	42	54	48.8
VII	D	April 25	May 25	30	46	65	53.0
	G	March 21	May 4	42	39	49	46.9
VIII	F	April 23	May 22	29	43	55	50.5

1. Duration

Table 4 gives the details concerning the duration of the yolk sac period at the different hatcheries. As with the incubation period,

there is considerable variation in the length, but the causes are more clearly indicated.

Hatchery: Environment plays an important role, as the period varies with the individual hatchery rather than the source of the eggs. Hatchery V eggs from three sources were remarkably consistent as regards the duration of the yolk sac period, requiring forty-nine to fifty-three days as contrasted with thirty and sixty-five elsewhere for the same eggs. At Hatchery II two sources gave fifty-nine and sixty-three as contrasted with thirty-three elsewhere, and at Hatchery VI two sources gave thirty as contrasted with twenty-nine and fifty elsewhere.

Source: The source of the eggs exerts so small an influence that the results are within the range of experimental error. At Hatchery II River C eggs were a few days in advance of River B eggs. At Hatchery V the River D and River E eggs were a few days ahead of the River A eggs. In no instance was there any appreciable difference in the duration of the yolk sac stage when the time of hatching was comparable.

Date of Hatching: If the hatcheries are arranged according to the date of hatching, in general the duration of the yolk sac period becomes shorter with the advance of the date of hatching. There are two exceptions, the River G fry at Hatchery VIII, where the temperature is higher, and Hatchery II, where the water is still cold late in the season. The difference between the hatcheries with early and late hatching is largely due to the temperature of the water.

Temperature: Temperature is the controlling factor in determining the duration of the yolk sac period. If the hatcheries are grouped in order of the temperature of the water during the yolk sac period, as in Table 5, it will be found that the length of the yolk sac period becomes shorter as the temperature becomes higher. At Hatchery VII with River D fry the duration of the yolk sac period, which started April 25, and had an average temperature of 58° F., was thirty days as compared with forty-two days for River G fry, which hatched on March 21 and were subjected to an average temperature of 46.9°.

TABLE 5. WATER TEMPERATURE AND DURATION OF YOLK SAC PERIOD

Hatchery	Average Temperature of Water (Fahrenheit)	Duration of Yolk Sac Period (Days)
I	40.0	65
II	42.1	61
V	42.2	51
VII (G fry)	43.9	42
VI	47.2	31
IV	48.0	30
III	48.3	33
VIII	50.3	29
VII (D fry)	54.7	30

The temperature at the end of the yolk sac stage is without significance except as it reflects the average temperature during the

period. The hatcheries fall in about the same order as when grouped for the average temperature. There is no definite temperature for the termination of the yolk sac period, as there is a wide range from 46° to 65° F.

Spring- vs. Fall-Run Salmon: There is no difference in the duration of the yolk sac stage for eggs from fall- or spring-run salmon.

Size of Egg: The duration of the yolk sac period is not influenced by the size of the egg.

Incubation Period: The length of the incubation period has no relation to the length of the yolk sac period. At Hatchery I an incubation period of 120 days was followed by a yolk sac period of sixty-five days. At Hatchery IV an incubation period of 192 days was followed by a yolk sac period of thirty days.

2. Size of Yolk Sac and Fry

The size of the yolk sac and fry depends upon the size of the egg. The weight of the yolk sac is about 63% of the combined weight of the sac and fry. If the salmon fry of the various rivers are arranged according to the weight of the yolk sac and fry, they show a surprising uniformity both in the combined weights and the weight of the yolk sac even at the different hatcheries. The two lots of River C fry were evidently taken from different lots of large and small salmon.

TABLE 6. WEIGHT OF YOLK SAC AND FRY

River	Weight of Yolk Sac and Fry in Grams	Yolk Sac	
		Weight in Grams	Per Cent
B	.182	.119	60
F	.158-.160	.100-.100	63
C (Hatchery VII)	.148	.099	67
A	.141-.142	.087-.085	59
D	.134-.134	.081-.081	61
	.137-.139	.080-.089	—
E	.122	.079	65
C (Hatchery II)	.121	.072	60
G	.117	.083	71

Increase in Size: As the yolk sac period advances the weight of the fry increases while that of the yolk sac decreases. However, the combined weight instead of remaining constant also increases. This is shown by comparing the average of the first three weeks against the last three or by taking the mean increase for the series. Similar results are obtained by either method and indicate that there is a definite increase in weight as the period advances. The per cent increases for the different rivers are: A, 103-103; B, 109; C, 112-122; D, 105-105-106-106; E, 111; F, 107-115; G, 113.

No difference is noted between the large and the small eggs, the average for the two groups being equal. The increase appears more or less characteristic for the individual river. The increase is probably due to the absorption of fluid rather than to the intake of food,

since observations of hatchery superintendents indicate that feeding does not take place during the yolk sac period.

3. Absorption of the Yolk Sac

The rate of absorption of the yolk sac is not dependent on the source of the eggs. It varies with the hatchery, as the duration is largely controlled by temperature. Table 7 gives the changes in the weight of the yolk sac in the different hatcheries. It varies with both the individual hatchery and with the length of the yolk sac period. The most rapid rate of absorption was observed at Hatchery VIII.

The size of the egg causes little difference in the rate of absorption of the yolk sac. The large yolk sac requires a slightly longer time, but absorption is so fast that there is little difference at the end of the period. This fact is demonstrated by comparing River B fry with large and River C fry with small yolk sacs at Hatchery II and River D and River F eggs at Hatchery VI. At Hatchery II the large yolk sacs were absorbed in sixty-three days as compared with fifty-nine for the small, and at Hatchery VI thirty-two days as compared with thirty.

TABLE 7. THE ABSORPTION OF THE YOLK SAC
(Weight in Grams)

	Hatcheries											
	I	II		III	IV	V		VI			VII	VIII
	Rivers											
Weeks	A	B	C	C	D	D	A	E	D	F	D	G	F
0	.085	.119	.072	.099	.081	.081	.087	.079	.080	.100	.089	.083	.100
1	.083	.116	.070	.095	.076	.079	.085	.077	.074	.097	.086	.078	.082
2	.079	.111	.068	.080	.065	.076	.083	.075	.067	.091	.081	.073	.060
3	.074	.105	.066	.057	.049	.072	.079	.073	.054	.077	.067	.065	.035
4	.068	.098	.062	.028	.013	.066	.073	.067	.020	.040	.035	.055	.004
5	.062	.087	.057	—	—	.054	.064	.057	—	—	—	.034	—
6	.053	.073	.049	—	—	.033	.051	.032	—	—	—	—	—
7	.040	.056	.036	—	—	.002	.024	—	—	—	—	—	—
8	.025	.035	.017	—	—	—	—	—	—	—	—	—	—
9	.005	.007	—	—	—	—	—	—	—	—	—	—	—

4. Length and Weight of Fry During Yolk Sac Period

The length and weight of the salmon fry at the various hatcheries at weekly intervals is given in Tables 8 and 9. The rate of growth varies with the different hatcheries and river sources of the fry.

Size of Egg: The size of the egg, which in part depends upon heredity and in part upon the size of the parent fish, in general determines the length and weight of the salmon at the end of the yolk sac period. The eggs from three rivers were large and produced fry with an average length of 28.8 mm. and a weight of .160 gms. as compared with small eggs from five rivers which produced fry averaging 26.0 mm. and .106 gms., respectively.

In two hatcheries an opportunity was given for the comparison of large and small eggs. In Hatchery II the fry from the larger eggs were longer and heavier. In Hatchery VI the fry from the large eggs were longer and of about the same weight.

Length of Yolk Sac Period: Irrespective of the length of the yolk sac period, there is little difference in the length and weight of the fry at the end of the period. The slight difference in length is in favor of the longer period, 28.1 vs. 27.5 mm.

Spring- vs. Fall-Run Salmon: Practically no difference was found between the fry of spring- and fall-run salmon. The spring-run fry average 27.6 mm. in length and .132 grams in weight. The fall-run fry averaged 26.5 mm. in length and .132 grams in weight.

Temperature: The temperature of the water has little effect on the length and weight of the fry at the end of the yolk sac period. Low temperature gives a more prolonged yolk sac period, and consequently the fry are very slightly longer and heavier in the colder waters.

Source: The eggs from one river tend to produce fry of about the same length and weight even at different hatcheries, but hatchery conditions modify the findings so that no clear-cut results can be obtained.

Hatchery: The environment of the hatchery affects the size of the fry only to a slight extent, chiefly the length of the yolk sac period. The difference in fry from several sources at the same hatchery indicates that hereditary influences predominate.

TABLE 8

LENGTH OF SALMON FRY DURING YOLK SAC AND FEEDING PERIODS
(Length in Millimeters)

	Hatcheries												
	I	II		III	IV	V			VI		VII		VIII
	Rivers												
Weeks	A	B	C	C	D	D	A	E	D	F	D	G	F
0	17.7	18.8	18.0	18.3	20.0	18.1	18.2	17.6	17.5	17.5	17.1	17.2	20.2
1	18.8	20.0	19.4	20.7	21.5	19.1	19.2	18.1	19.8	20.0	19.2	18.6	22.2
2	19.9	21.2	20.4	23.1	23.0	20.1	20.2	20.1	21.8	22.3	21.2	19.9	24.3
3	20.9	22.4	21.5	25.5	24.5	21.1	21.2	21.3	23.8	24.7	23.4	21.2	26.4
4	22.0	23.6	22.5	28.0	26.0	22.1	22.2	22.5	25.8	27.2	25.5	22.6	28.3
5	23.0	24.8	23.6	28.9	26.6	23.1	23.2	23.6	26.8	28.0	27.6	23.9	29.3
6	24.1	26.0	24.6	29.7	27.3	24.1	24.2	24.8	27.9	28.8	29.7	25.2	30.3
7	25.1	27.3	25.7	30.6	28.0	25.1	25.2	25.6	29.0	29.6	31.8	26.1	31.5
8	26.2	28.5	26.8	31.5	29.6	26.1	26.0	26.3	30.1	30.4	33.9	27.1	32.3
9	27.3	29.8	27.2	34.3	31.3	26.5	26.8		35.6	33.6	36.0	28.0	34.4
10	28.1	29.8	27.4	37.1	33.0	27.0	27.6		37.0	36.7	38.2	29.0	36.6
11	28.9	29.8	27.7	39.9	34.7				40.5	39.8	40.3	31.6	38.8
12	30.9			42.7	36.4				43.9	42.9	42.3	34.0	40.9
13	32.9			45.5	38.1				47.6	46.0	44.4	36.4	43.0
14	35.0			48.3	39.7				51.1	49.1	46.4	38.9	45.1
15				51.1	41.4				54.6	52.2	48.5	41.3	
16				53.9					58.0	55.1	50.6	43.7	
17				56.7								46.0	
18												48.5	
19												51.0	
20												53.6	
21												56.0	
*	65	63	59	33	30	50	53	49	30	32	30	42	29
**	27.5	29.8	27.0	28.6	26.2	25.2	25.7	25.6	26.05	27.6	25.8	25.2	28.4

*Duration of yolk sac period, days.
**Length at end of yolk sac period.

Feeding Period

With the absorption of the yolk sac the salmon is said to begin to feed. Shortly after the start of this period the scales begin to appear. After the young salmon has become accustomed to feeding, growth proceeds at a more or less rapid rate, varying markedly with the hatchery.

Since the young salmon were liberated at different times the material from some of the hatcheries terminated earlier than that from others. As a result, our records end at various times between eleven and twenty-one weeks after hatching.

In six of the hatcheries the records extend fourteen weeks after the date of hatching. Of these six hatcheries five have a yolk sac period of slightly over four weeks, so that the feeding period has a uniform start and extends over ten weeks.

TABLE 9

WEIGHT OF SALMON FRY DURING YOLK SAC AND FEEDING PERIODS

(Weight in Grams)

	Hatcheries												
	I	II		III	IV	V			VI		VII		VIII
	Rivers												
Weeks	A	B	C	C	D	D	A	E	D	F	D	G	F
0	.036	.040	.034	.035	.034	.039	.044	.034	.035	.040	.031	.030	.046
1	.038	.045	.036	.055	.050	.045	.050	.039	.046	.055	.038	.032	.075
2	.043	.053	.039	.077	.068	.056	.057	.045	.066	.072	.055	.037	.105
3	.048	.064	.046	.105	.087	.065	.065	.052	.090	.092	.083	.045	.128
4	.054	.076	.057	.137	.105	.077	.074	.060	.122	.116	.125	.055	.170
5	.064	.090	.072	.175	.125	.089	.085	.072	.158	.143	.175	.067	.208
6	.079	.104	.090	.215	.149	.103	.100	.087	.197	.183	.225	.085	.245
7	.101	.119	.108	.255	.185	.119	.119	.103	.245	.238	.285	.110	.290
8	.123	.137	.128	.303	.244	.141	.140	.122	.315	.305	.355	.140	.335
9	.149	.162	.147	.365	.309	.176	.165		.405	.395	.430	.180	.380
10	.175	.192	.170	.435	.322	.203	.190		.525	.505	.510	.230	.435
11	.202	.223	.190	.530	.383				.680	.620	.595	.295	.490
12	.241			.665	.461				.845	.755	.675	.385	.545
13	.311			.820	.556				1.020	.905	.765	.500	.600
14	.411			1.030	.663				1.210	1.065	.860	.615	.660
15				1.260	.779				1.400	1.240	.965	.730	
16				1.500					1.600	1.420	1.070	.860	
17				1.830								.990	
18												1.120	
19												1.250	
20												1.390	
21												1.530	
*	65	63	59	33	30	50	53	49	30	32	30	42	29
**	.057	.162	.136	.164	.111	.122	.131	.103	.132	.132	.139	.085	.177

*Days of yolk sac period.
**Weight at end of yolk sac period.

Period of Lag: In practically all the hatcheries during the first four weeks of the feeding period the growth of the fry is at a slower rate than during the yolk sac stage and during the period after the fourth week of feeding. This difference in rate is not so noticeable

in the weight curves which have been smoothed to fit the subsequent growth, but is quite noticeable when lengths are charted. The increase in length against time, usually a straight line, has about the same angle for the yolk sac period and the late feeding period. The angle for the early feeding period of four weeks is more acute, indicating slower growth. In Hatcheries II and V, in which the records extend only eleven weeks, this lag in growth is most pronounced. In certain hatcheries the lag period terminates after three weeks, but in most hatcheries after four. Hatchery VIII showed no evidence of the lag.

The lag is a general phenomenon of growth. It is found not infrequently when organisms are transplanted to a new environment, and constitutes the period of adaptation to a changed existence. The salmon fry evidently require a period of adjustment to the feeding conditions of the hatchery and consequently are not actively feeding to the best advantage until the end of the fourth week.

Whether the lag phenomenon occurs under natural feeding conditions in the rivers is impossible to predict. Probably it occurs, but it may be less pronounced than with artificial feeding at the hatcheries. This observation indicates the need of experimental work on the feeding of salmon fry during the first four weeks of the feeding period. It is possible that a more suitable food at the start of the feeding period would eliminate at least in part this retardation.

Source: The growth of the salmon fry is influenced to a slight extent by the river source of the eggs. At Hatchery VII, River D fry fourteen weeks old weighed .860 grams and measured 46.4 mm., and River G fry .860 grams and 43.7 mm. At Hatchery VI, River D fry weighed 1.210 grams and measured 51.1 mm., and River F fry 1.065 grams and 49.1 mm. However, there is a tendency toward uniformity under the hatchery conditions.

Hatchery: The environment of the hatchery has a noticeable influence upon the growth of the fry. River D fry fourteen weeks old at three hatcheries showed considerable variation in growth, as did River F fry at two hatcheries.

TABLE 10

HATCHERY ENVIRONMENT AND GROWTH OF FRY

River	Hatchery	Length in Millimeters	Weight in Grams
D	IV	39.7	.663
D	VI	51.1	1.210
D	VII	46.4	.860
F	VI	49.1	1.065
F	VIII	45.1	.660

Temperature: The variation in the growth of fry in the several hatcheries is marked in spite of the uniformity of the average temperature of the water in all hatcheries except Hatcheries VII and

VIII. Water temperature, within the range of 58° to 64° F. during the feeding period evidently does not influence the growth of artificially reared fry. Environmental conditions such as the containers, flow of water, composition of the water, and food probably produce these variations, in as much as the range of temperature is not sufficient to affect materially metabolism and its effect on growth. The marked effect of a low water temperature during this period is shown in the case of a hatchery where the water was consistently below 50° F. and the growth was greatly retarded. Evidently salmon require a higher temperature than brook trout for their optimum growth.

The date of hatching which is associated with temperature has no bearing on the problem, as the eggs hatched at these hatcheries within a short time of each other. In Hatchery VII, River G eggs hatched earlier than River D, with a slower yolk sac period. In the same number of feeding weeks there was only a slight difference in favor of the River D fry in three degrees warmer water.

TABLE 11

WATER TEMPERATURE AND GROWTH OF FRY

Hatchery	River	Temperature (Average)	Length	Weight
IV	D	58.2	39.7	.663
VI	D	59.4	51.1	1.219
	F	59.4	49.1	1.065
VII	G	59.6	43.7	.860
III	C	60.8	48.3	1.030
VII	D	62.6	46.4	.860
VIII	F	64.4	45.1	.660

Size of Egg: Fry from two of the rivers were from large eggs and two from small. The large eggs produced slightly larger fry, averaging .947 grams vs. .886, and 47.7 mm. vs. 44.7 mm. The difference is rather slight and indicates a tendency for the small egg fry to catch up with the large egg fry. However, during hatchery life the large egg ordinarily should give larger fry than the small.

Spring- vs. Fall-Run Salmon: No difference was found between spring- and fall-run salmon fry. The average weight and length for each class was about the same.

SUMMARY

1. A comparison of the development of eggs and fry of salmon from seven rivers distributed in eight hatcheries is reported. Results furnish confirmatory evidence of river varieties of salmon.

2. The size of the egg depends not only upon the size of the parent salmon but also upon the river source. It is the principal factor determining the size of the fry during the yolk sac period. It also affects the growth of the salmon in the feeding period.

3. Heredity, as expressed by the river source of the eggs, is an important factor regulating the time of spawning and the duration of the incubation period. It is of little if any importance in the duration of the yolk sac stage. It has some slight influence on the growth of the salmon during the feeding period.

4. Environment, as typified by the hatchery, has little influence on the time of spawning and the incubation period, but plays an important role in regulating the length of the yolk sac period and the growth of the salmon during the feeding period.

5. Temperature is the most prominent factor in the environment and largely controls the duration of the yolk sac period. It is not an important factor in the development of the fry during the feeding period, except below 50 degrees F. it causes marked retardation of growth. It only produces a marked shortening of the incubation period when over 42 degrees F.

6. There is an increase in the combined weight of yolk sac and fry as the yolk sac period advances. This phenomenon is either due to the absorption of fluid or possibly to the intake of food.

7. During the first four weeks of the feeding period there is a lag in the rate of growth which may be explained by slow adaptation to feeding conditions. Further studies of the feeding habits of the salmon during this period may disclose methods of feeding which will eliminate or reduce this lag.

8. No difference in the incubation period, the yolk sac period, or in the growth of the fry during the feeding period was found in the eggs of spring-run and fall-run salmon. These meager observations favor the view that there is no specific difference between the two runs of salmon.

9. The scales of the salmon first appear at the beginning of the feeding period.

KEY TO HATCHERIES

I. Morell River, P. E. I.	V. Margaree, N. S.
II. Restigouche, N. B.	VI. Antigonish, N. S.
III. St. John, N. B.	VII. Middleton, N. S.
IV. Miramichi, N. B.	VIII. Bedford, N. S.

KEY TO RIVER SOURCES OF SALMON EGGS

A. Morell river.	E. Margaree river.
B. Restigouche river.	F. River Philip.
C. St. John river.	G. Nictaux river.
D. Miramichi river.	

FISH CULTURAL ACTIVITIES OF THE PROVINCE OF QUEBEC

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The purpose of this paper is to outline briefly the fish cultural activities of the Province of Quebec. The Hatchery Branch of the Department of Colonization, Game and Fisheries has operated, since 1922, two salmon hatcheries which together handle six to seven millions of salmon eggs to the fry stage. Prior to 1922 these hatcheries were administered by the federal government and were under the supervision of Mr. J. A. Rodd.

One of these hatcheries is situated in Tadoussac, a small village at the mouth of the Saguenay river, a tributary of the St. Lawrence. The other is on the Atlantic coast at Gaspe. Parent fish are captured as they ascend the rivers during the months of June and July and are retained in a freshwater pond at Gaspe and in a saltwater pond at Tadoussac until the spawning time in the latter part of October.

Some efforts are now being made to raise a number of salmon to the fingerling stage at each of these locations. The work is undertaken at this time in order to have men for the future with experience in the raising of fingerlings. As far as our experience goes the rearing of salmon fingerlings is likely to present fewer difficulties than is the case with speckled trout. It is not probable that the Department will be prepared to raise salmon fingerlings on a large scale for several years. Nevertheless it is realized that such work is desirable and may be inevitable, consequently we are preparing ourselves in anticipation. The immediate concern of the Hatchery Service is to raise increasingly large numbers of brook trout fingerlings and yearlings for distribution to waters that have been subjected to heavy fishing over a period of years. These two salmon hatcheries collect large quantities of trout eggs for distribution to the other hatcheries in the Province.

Since 1914 the Department has also operated four brook trout hatcheries. The species of trout handled include brook trout, grey trout and rainbow trout. Until recent years, generally speaking, fish from these four hatcheries have been planted as fry. Only rainbows were carried to the fingerling stage and a small percentage of these were held until the yearling stage before they were planted. The establishment for the rearing of rainbows is situated at Baldwin's Mills, close to the Vermont border, and has a consistently good rec-

ord in producing brook trout fingerlings in recent years and the production of rainbows for over twenty years.

It may be of interest at this point to observe that when it is a question of planting fish of a species indigenous to the waters concerned, it is difficult to estimate the results and value of the effort made. However, when the species to be planted is not indigenous, as in the case of rainbows, it is not too difficult to determine in a general way the success or failure of the introduction of the new species. There can be no doubt that the planting of rainbow trout in the waters of the eastern townships has been a successful fish cultural undertaking. I am careful to say fish cultural undertaking, since there is some objection to the introduction of this species into some of the waters in the district mentioned on the score of competing with the native brook trout. It is my own opinion that rainbow trout do not stay long in the smaller and cooler brook trout streams, but migrate as they increase in size to the larger and warmer streams where brook trout were scarce before the introduction of rainbow. The success of this introduction is indicated by the fishing now afforded, which is good, and by the frequent specimens observed and secured by our fisheries inspectors.

Although a brood stock of rainbows is maintained at Baldwin's Mills, eggs from wild trout were secured from three different places this spring, which surely shows that these fish are now established. It is of interest to us to observe that the hatch and resultant production from all of these wild eggs were superior to that secured from the eggs of the brood stock. It is intended to limit the number of rainbow fingerlings to between 75,000 and 100,000 annually and to build up an output of 200,000 brook trout, possibly for next year. There is without doubt a sufficient supply of water on hand to warrant such an extension.

As has already been said, the above mentioned hatchery, until the last three or four years, was the only one in the Province to carry fish to the fingerling stage. In 1928 the raising of fingerlings was commenced at the other hatcheries, including the salmon hatcheries. As a result of these efforts the hatchery at St. Alexis (Maskinonge county) has been judged suitable for the rearing of trout fingerlings and yearlings, although our record there has never been free of difficulty and trouble. At Mont Tremblant (Terrebonne county) better success has been attained with the rearing of grey than of brook trout, and in future only grey trout will be cultured there. The hatchery at Magog, because of pollution and excessively high water temperatures, is unsuitable for the rearing of either salmon or any of the trout we handle. Its future usefulness to the Department will be in the cultivation of smallmouth black bass fingerlings.

It did not take long to realize that our hatcheries and their situations were quite inadequate to permit the raising of the necessary number of fingerlings. The existing facilities were improved where

possible, notably at Baldwin's Mills. In addition, a small rearing station was built in 1931 at Ste. Agathe des Monts and yielded 40,000 fingerlings that year. This year the station will yield over 70,000 fingerlings and this figure represents its present capacity. It is intended to increase the capacity of this station to 500,000 fingerlings, since there is at hand a source of water suitable for fisheries purposes which is capable of furnishing more than 500 gallons of water a minute.

Another rearing station was commenced at Gaspe in this same year and is in the process of completion at the time of writing. There is at this location a fine supply of over 100 gallons per minute of spring water at the minimum flow. The temperature of this water at the source is 42° F., summer and winter. A nearby creek, whose water temperature is suitable, furnishes additional water. In 1931 only spring water was available. Sixty thousand brook trout were raised that year, but due to the difficulty of raising the temperature of the water the size of these fish did not compare to those raised elsewhere. This summer the water of the creek has been made available and 100,000 brook trout and 100,000 salmon have been carried to date. This number represents approximately the capacity of the plant, but as funds are available it may be possible to increase its supply of water. This undertaking, however, will be postponed until facilities in the more densely populated portions of the Province are considerably extended. This rearing station will serve to supplement the efforts of the hatcheries and stations elsewhere, since there is no pressing need of extensive planting of trout in the district that would normally be served.

One may mention in passing that the Hatchery Service has reserved for its own use four fine trout lakes in the district of Gaspe. Over a million trout eggs were obtained from these lakes last year and a similar quantity the year before. Lakes are also reserved for this purpose in the neighborhood of Tadoussac and three more are to be used this year. It is indeed fortunate that these two hatcheries are so well situated not only for the collection of salmon eggs but also for the collection of trout eggs. It is no exaggeration to say that the supply of eggs from these sources will be unlimited for many years to come.

The hatchery at Magog has been used for the incubation of eggs of grey and brook trout. It has been found unsuitable for the care of these eggs for the reasons already mentioned (i. e., pollution and high temperatures). The situation of this hatchery, however, appears to be excellent for the rearing of smallmouth black bass. The water used is taken from the Magog river, the discharge of Lake Memphremagog. As the water leaves the lake it is unpolluted, but shortly thereafter sewage in considerable amounts enters the river from the town. The land on which two rearing pools for black bass have

been built is separated from the river by a dyke and is below the water level. The river is very rich in plankton, as one would expect. The yield from the two ponds has not yet been determined; the fish are just now being distributed. No difficulty was experienced in maintaining a supply of Daphnia, but we had far less success in the securing of minnows for our fingerlings.

With a view to undertake the rearing of ouananiche or freshwater salmon, inquiries were made in the Lake St. John district in the winter of 1930. So encouraging was the information received of their number and size in the Rivière aux Saumons, four miles from St. Felicien, that preparations for their capture the following summer were made. Two hundred and eighty ouananiche, ranging from four to eight pounds, were captured and retained until the fall. At this time 500,000 eggs were taken. A temporary hatchery was constructed in which to incubate these eggs. Shipments of ouananiche eggs were made early in February, 1932, to every hatchery in the Province except Magog. It was desired to have as wide an experience with these eggs as possible. Only a small number were distributed as fry. As far as this year's experience is concerned, it is safe to say that ouananiche at St. Felicien, not only for the size attained, but also for the loss suffered, have turned out better than the ouananiche raised in any of the other hatcheries. The temperature of the water at this site runs from 65° to 70° F. during the warmer months of this summer. Only on one or two occasions at the most did it reach 72°. The supply of water is enormous, thousands of gallons a second. Sixty thousand fingerlings were carried this season. It is not yet decided the number to be carried next year, though it is expected to be larger. The run of adult ouananiche this year is larger, not only in numbers, but in size than last year. At present there are 385 adults in our retaining pond, so that we look forward to a considerable increase in the number of eggs taken.

It has been the practice to distribute fish from the hatcheries of the Province according to the application method. This method has very serious drawbacks. With the realization of these drawbacks, an inspection service has been inaugurated to survey the waters in those counties south of the St. Lawrence with a view to distributing the fish direct from the hatcheries on recommendations from the office. North of the St. Lawrence inspections have been made of lakes for which applications have been submitted. It should be possible within the next three or four years to stock the waters of the counties south of the St. Lawrence directly and to abolish the application method there. It will take longer to do away with the application method in those counties north of the St. Lawrence.

ARTIFICIAL FOOD RATIONS FOR SOCKEYE SALMON

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The need for artificial food rations for sockeye salmon has arisen but recently. The common practice in British Columbia in past years has been to liberate the sockeye from the hatcheries as soon as free-swimming or shortly thereafter, in the belief that benefit is derived and expense curtailed by returning the fry to their natural environment at the earliest possible stage.

Cognizant, however, of the advantages claimed in other districts, but with different species, for an extended period of retention prior to liberation, whereby a certain period of protection from enemies is allowed and a greater chance of survival by reason of increased size is achieved, the Department of Fisheries has recently undertaken experiments on the pond retention of young sockeye. The efficiency and economical value of such pond retention is now being determined but in view of the possibility of such practice becoming general the desirability of having data concerning cheap, satisfying food rations was apparent and has led to these food studies.

A survey of the literature on the subject of artificial food rations discloses that much valuable work has been done in recent years but the results reported present a maze of disconnected and sometimes contradictory evidence. The factors of species of fish and age or size of individuals play such an important role in the reaction to foods that no application of results previously obtained seemed justified.

Artificial fish food studies may be divided into two types. They may, on the one hand, be strictly biochemical in nature, involving the use of a basal neutral medium to which are added definite amounts of nutrient materials, proteins, carbohydrates, fats, mineral salts, vitamins, factor H, etc., or they may be based on a more or less trial and error system, making use only of food materials already in use or capable of adoption.

The first type undoubtedly represents a more truly scientific attack upon the subject, but until some means is devised of accurately measuring the amount of food, or the amounts of the various foods in a mixed diet, actually consumed by the fish as differentiated from the amount dissolved and lost in the surrounding stream of water, and until some method of determining the effect of the various food rations upon the strength and vitality of the fish is found, the elaborate technique required for this fundamental study does not seem warranted. Furthermore, little attention is paid to the physical consistency of the food used or its palatability. The physical consistency of the food, i. e., the actual size of the particles as found in the water, is of great importance in the reaction of fry or fingerlings to

the food and should demand the same careful attention and measurement as the chemical content of the food.

In the study of the artificial food rations for sockeye salmon the second, more practical but more indefinite, method was adopted. Food rations already used for salmon were tested along with others embracing food materials which were thought to have some value. The important factors of adequate supply of food material, keeping and shipping qualities, and ease of preparation were duly taken into account.

The success of the various food rations was determined from a consideration and comparison of the growth rate and the mortality rate. The principal object of retention of sockeye salmon being to rear them only to a size when they would be better enabled to cope with the many destructive forces in their natural environment, the main essential was to produce a rapid, healthy growth.

The growth, generally, was computed from a measurement of the increase in length in millimeters, while the healthy condition of the fish was taken to be disclosed by the mortality rates. The data were collected at stated periods during the progress of the experiment and the variable reaction of the fry to the food as they advanced in size thus ascertained. No means were available, however, of measuring either the cumulative injurious effect of a poor food or the cumulative beneficial effect of a good food. Raw beef liver was used throughout as the control food, since with sockeye salmon, as with many other retained fishes, fresh, raw, beef liver has been found to be a very safe food for young fry and to produce good results.

While the arithmetic average has been calculated to represent the average length increase at each stage of the experiment, due regard has been had for the probable errors in sampling. Too strict adherence to the average as an accurate measure of growth, in studies of this nature, where samples are small and variations in length large, is unwarranted. Consequently throughout this experiment consideration has been given to the deviations which may reasonably be expected from the average length as recorded.

The deviations have been expressed as the standard deviation (S. D.) which measures the range of variation plus and minus from the average within which the chances are roughly two to one that any similarly collected samples would fall. In other words, 68% of any samples similarly obtained, would, under normal expectancy, fall within the limits of the standard deviation measured plus and minus from the average. The size of the standard deviation is thus indirectly a measure of the uniformity of the population from which the sample was taken.

For purposes of comparison, however, the coefficient of variation (C. of V.) has been calculated. Expressed as a percentage, this relationship of standard deviation to arithmetic average gives a relative value which may safely be used in direct comparison of variability. It is of particular significance in judging the degree of uniformity

of development which a food ration may produce, it being understood that a satisfactory ration should produce a more or less uniform growth rather than a highly variable population of numerous giants and many runts.

The necessity of using such statistical methods is obvious throughout this paper. Numerous illustrations can be found where direct comparison of the average length increases of two rations would clearly indicate a distinct advantage of one over the other. Consideration of the standard deviation of the samples, however, would, in most cases, show an overlapping of the deviations, thus tending to prove that the differences in average lengths were not significant but embraced within the probable errors of sampling.

The experiments were conducted during the summers of 1930, 1931, and 1932 at the Smith Falls Hatchery, Cultus Lake, B. C. Ordinary hatchery troughs, 16 ft. by 16 in. and containing roughly six inches of water, were used with a supply of from eight to ten gallons of water per minute. In 1930 and 1931 only 1,500 sockeye fry were used in each individual experiment, but in 1932 3,000 individuals made up an experimental lot. In 1930 the feeding tests were delayed one month and during this time ordinary rations of beef liver were given; in 1931 and 1932 the feedings commenced as soon as the fry were actually taking food.

In the initial experiment, 1930, the various foods were finely ground, mixed to a pastey consistency and fed in equal amount by volume. No definite measurement of the food was made other than that the amount was regulated by the quantity of beef liver which Lot No. 1, the control sample, would consume at a feeding. The feedings were given at regular two-hour intervals during the day, 8 A. M. to 5 P. M., but were later reduced to four feedings per day. In 1931, each ration was weighed, one-half pound per day, and in 1932 this amount was doubled since there were twice the number of fish per sample. The fry were thus allowed all the food they could consume at a feeding but no appreciable surplus was allowed to remain in the trough. Each trough was thoroughly cleaned every day.

The data accumulated during the experiments are tabulated in Table 1, but for general consideration and a better visual impression of the results of the various food-rations a graphic representation by means of a block diagram is given in Figure 1. Increase in length in millimeters is indicated in the upper section and percentages of mortality in the lower. Each step in the block represents approximately one two-week period of the experiment and the top of each block indicates the total increased length produced during the season. The total length of the fish may be computed by adding 24 mm. to the lengths shown for the 1930 series (lots 1-15), 26.2 mm. to the 1931 series (lots 16-39) and 25.2 mm. to the 1932 series, (lots 40-55). These lengths were the mean lengths of fifty specimens collected at random from the fry at the inception of the feeding tests.

Year	Lot	Length Increase mm.	S. D. mm.	C. of V.	Weight grams ×1,000	Losses No.	Losses %	Year	Lot	Length Increase mm.	S. D. mm.	C. of V.	Weight grams ×1,000	Losses No.	Losses %
1930	1	30.0	2.8	9.3	1,747	43	3	1931	29	37.9	6.7	17.7	2,592	30	2
June	2	20.9	3.6	17.2	910	551	37		30	32.1	3.5	10.9	1,864	147	10
22 to	3	26.2	6.6	25.2	1,450	103	7		31	31.0	6.3	20.3	1,919	144	10
Sept. 3	4	30.5	7.0	23.0	1,780	90	6		32	31.1	4.9	15.7	1,571	273	18
	5	29.7	5.8	19.5	1,780	58	4		33	32.9	4.2	12.7	1,939	50	3
	6	10.9	8.2	75.2	540	955	63		34	25.3	4.0	15.8	1,010	149	10
	7	14.0	6.9	49.3	660	112	7		35	24.1	5.5	22.8	1,129	170	11
	8	20.3	4.1	20.2	960	65	4		36	17.0	7.9	46.5	774	434	29
	9	26.8	3.9	14.5	1,630	72	5		37	32.5	5.9	18.2	1,912	254	17
	10	5.6	1.8	32.1	360	1,171	78		38	27.1	6.3	23.2	1,555	34	2
	11	21.0	2.9	13.8	1,250	146	10		39	25.9	6.6	25.5	1,421	87	6
	12	24.2	7.5	31.0	1,450	70	5	1932	40	30.7	3.0	9.7	1,715	59	2
	13	26.2	2.4	9.2	1,490	76	5	May	41	33.3	4.8	14.4	1,971	97	3
	14	21.3	5.8	27.2	1,155	75	5	24 to	42	27.5	4.5	16.4	1,587	117	4
	15	11.6	4.7	40.5	569	434	29	Aug. 24	43	25.4	4.8	19.0	1,264	410	14
1931	16	30.1	5.2	17.3	1,816	10	1		44	30.1	3.8	12.6	1,744	47	2
May	17	32.3	4.6	14.2	1,921	37	2		45	27.7	5.0	18.0	1,579	53	2
22 to	18	29.5	5.4	18.3	1,686	17	1		46	29.8	2.5	8.4	1,743	72	4
Aug. 22	19	32.3	7.7	23.8	1,997	19	1		47	20.4	5.7	28.0	1,034	111	4
	20	33.9	5.5	16.2	2,149	18	1		48	8.3	3.5	42.2	405	1,881	63
	21	34.9	4.4	12.6	2,161	21	1		49	4.5	2.5	55.5	232	2,496	83
	22	36.5	5.2	14.3	2,509	30	2		50	24.6	7.0	28.4	1,275	846	28
	23	35.7	7.7	21.6	2,392	442	30		51	25.6	10.9	46.2	1,542	1,184	40
	24	37.7	4.6	12.2	2,757	28	2		52	14.9	12.5	84.0	736	1,957	65
	25	36.6	7.9	21.6	2,493	49	3		53	29.1	15.6	53.6	1,755	1,208	40
	26	22.5	7.9	35.1	1,144	205	14		54	23.7	8.8	37.1	1,420	2,140	71
	27	17.7	9.5	53.7	846	247	16		55	29.2	8.2	28.1	1,968	580	19
	28	18.7	9.2	49.2	876	363	24								

TABLE 1. Records of average increase in length, average weight increase calculated for 1,000 individuals and total losses for the full experimental period of three months in 1930, 1931, and 1932. The length increases have been treated statistically to show the standard deviation from each arithmetic average and the coefficient of variation for each sample.

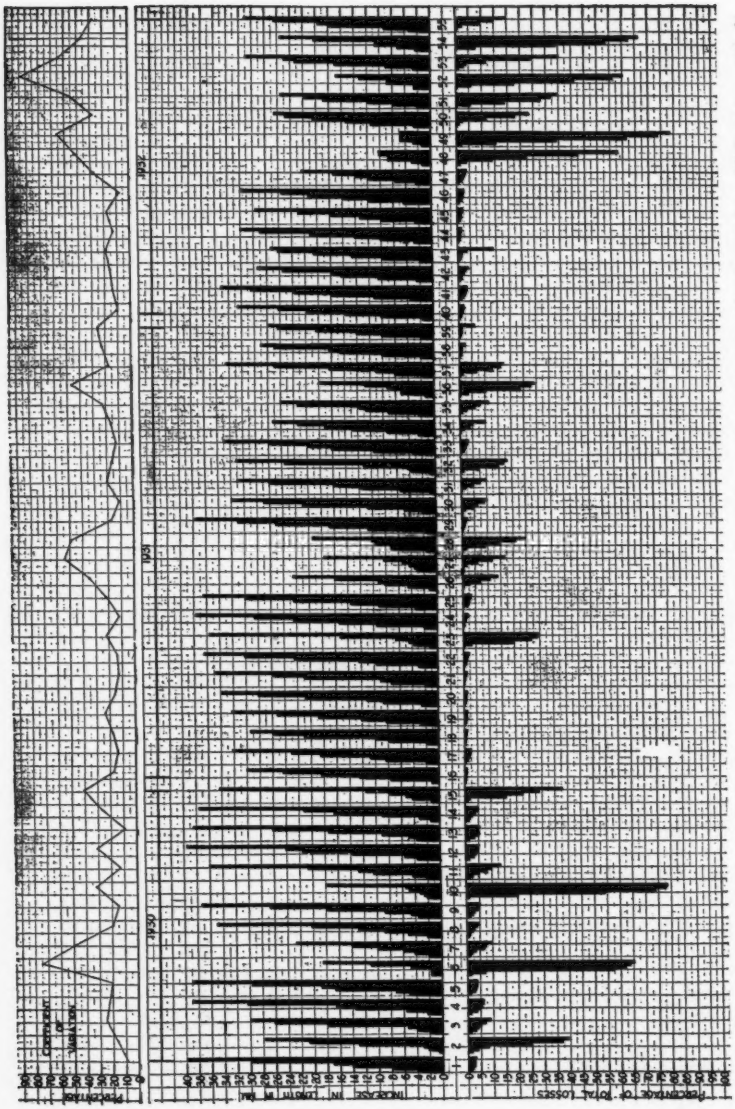

Figure 1. Block diagram indicating in the upper section the average length increases in millimeters and in the lower section the percentage of mortality, at the end of each of six periods during the summers of 1930, 1931, and 1932. Along the top of the chart are plotted the coefficients of variation for total length increase to September 3rd for 1930, August 22nd for 1931, and August 24th for 1932.

Figure 1. Block diagram indicating in the upper section the average length increases in millimeters and in the lower section the percentage of mortality, at the end of each of six periods during the summers of 1930, 1931, and 1932. Along the top of the chart are plotted the coefficients of variation for total length increase to September 3rd for 1930, August 22nd for 1931, and August 24th for 1932.

LIST OF FOOD RATIONS USED IN EXPERIMENTS

Year	Lot	Ration	Year	Lot	Ration
1930	1	B.L. —100 Control	1931 cont'd	29	B.L. — 50 + D.S.E. — 50
	2	F.S.O. —100		30	C.S. — 50 + D.S.E. — 50
	3	F.S.O. — 75 + B.L. — 25		31	C.S. — 75 + D.S.E. — 25
	4	F.S.O. — 50 + B.L. — 50		32	H.M. — 50 + D.S.E. — 50
	5	F.S.O. — 25 + B.L. — 75		33	B.L. — 50 + D.S.M. — 50
	6	C.S. —100		34	C.S. — 50 + D.S.M. — 50
	7	C.S. — 75 + B.L. — 25		35	C.S. — 75 + D.S.M. — 25
	8	C.S. — 50 + B.L. — 50		36	H.M. — 50 + D.S.M. — 50
	9	C.S. — 25 + B.L. — 75		37	H.M. — 33 + D.S.E. — 33 + D.S.M. — 33
	10	H.M. —100		38	Commercial Fish Paste
	11	H.M. — 75 + B.L. — 25		39	C.S. — 50 + H.M. — 50 (Fed alternately)
	12	H.M. — 50 + B.L. — 50	1932	40	B.L. —100 Control
	13	H.M. — 25 + B.L. — 75		41	B.L. — 50 + D.S.E. — 50
	14	B.L. — 33 + F.S.O. — 33 + C.S. — 33		42	B.L. — 50 + H.M. — 50
	15	F.S.O. — 33 + C.S. — 33 + H.M. — 33		43	B.L. — 33 + C.S. — 33 + H.M. — 33
1931	16	B.L. —100 Control		44	B.L. —100, 1st mo.
	17	B.L. —100, 1st mo.			B.L. — 50 + H.M. — 50, 2nd mo.
		B.L. — 50 + C.S. — 50, 2nd mo.			B.L. — 33 + C.S. — 33 + H.M. — 33, 3rd mo.
		C.S. —100, 3rd mo.		45	B.L. —100, 1st mo.
	18	B.L. —100, 1st mo.			B.L. — 50 + C.S. — 50, 2nd mo.
		B.L. — 50 + H.M. — 50, 2nd mo.			B.L. — 33 + C.S. — 33 + H.M. — 33, 3rd mo.
		H.M. —100, 3rd mo.		46	B.L. — 50 + D.S.M. — 50
	19	B.L. —100, 1st mo.		47	B.L. — 50 + C.S. — 50
		B.L. — 50 + C.S. — 50, 2nd mo.		48	Commercial Fish Paste
		B.L. — 33 + C.S. — 33 + H.M. — 33, 3rd mo.		49	Commercial Fry Food Meal
	20	B.L. —100, 1st mo.		50	D.S.E. — 50 + R.O. — 20 + D.S.M. — 10 + B.L. — 20, 1st mo.
		B.L. — 50 + H.M. — 50, 2nd mo.			D.S.E. — 50 + R.O. — 20 + C.S. — 30, 2nd mo.
		B.L. — 33 + C.S. — 33 + H.M. — 33, 3rd mo.			D.S.E. — 50 + C.S. — 50, 3rd mo.
	21	B.L. — 50 + C.S. — 50		51	C.S. — 50 + D.S.M. — 25 + D.S.E. — 25
	22	B.L. — 50 + H.M. — 50		52	C.S. — 50 + D.S.M. — 10 + D.S.E. — 10 + R.O. — 30
	23	C.S. — 50 + H.M. — 50		53	B.L. — 50 + He.M. — 50
	24	B.L. — 33 + C.S. — 33 + H.M. — 33		54	C.S. — 30 + He.M. — 30 + D.S.E. — 20 + D.S.M. — 20
	25	B.L. — 50 + F.S.E. — 50		55	He.M. — 30 + D.S.M. — 20 + D.S.E. — 20 + B.L. — 30, 1st mo.
	26	C.S. — 50 + F.S.E. — 50			He.M. — 25 + D.S.M. — 25 + D.S.E. — 25 + C.S. — 25, 2nd + 3rd mo.
	27	C.S. — 75 + F.S.E. — 25			
	28	H.M. — 50 + F.S.E. — 50			

List of food rations used during 1930, 1931, and 1932, showing percentage of each constituent contained. Abbreviations are: B.L.—beef liver; C.S.—canned salmon; H.M.—halibut meal. F.S.O.—frozen salmon offal; F.S.E.—fresh salmon eggs; D.S.E.—dried salmon egg meal; D.S.M.—dried skim milk; R.O.—rolled oats; and He.M.—herring meal.

Along the top of the diagram is plotted the coefficient of variation for each sample in order to indicate readily the relative variations from the average length increases computed at the end of the second last step or experimental period, September 3rd. While the 1930 tests were continued to October 3rd, and are so represented on the diagram, the tabulated results and the discussion thereof are confined to the increase in length attained to September 3rd, since this date more nearly coincides with the concluding date for the 1931 and 1932 experiments.

The first season's experiments were designed fundamentally to disclose the value and importance of raw beef liver as a food for retained sockeye and to indicate the limits to which it might be reduced in a mixed ration. The other ingredients used were those available during the season in quantity and at a low cost. The frozen salmon offal, not necessarily sockeye, was obtained from a salmon cannery. The canned salmon was a cheap commercial grade. The halibut meal was obtained from a reduction plant.

It is at once evident that the frozen salmon (Lot 2), canned salmon (Lot 6) and halibut meal (Lot 10) are, of themselves, poor foods. They varied in effect in the above order and their progressive inadequacy is reflected in the mortality columns. The calculation of the average length increase for canned salmon—10.9 mm.—must be taken with greater reservation than would apply to the other averages since the standard deviation from the mean—8.2 mm.—and the coefficient of variation—75.2%—would indicate a very heterogeneous assortment of length increases.

Length increased and mortality decreased definitely and progressively with the addition of 25% and 50% raw beef liver, but the value of further increasing the liver content to 75% is not so obvious. In these latter samples, however, the deviations from the average and the coefficients of variation are reduced, thus tending to indicate a more uniform development. The addition of increasing amounts of beef liver notably stimulated development during the earlier stages but no pronounced effect on reduction of mortality occurred until the later periods.

The importance of beef liver as an item in the diet is also noted in a comparison of the growth rates and mortality counts for Lots 14 and 15. The former was fed a one-third ration of beef liver, while the latter was given no liver, halibut meal being substituted. The beef liver-frozen salmon offal-canned salmon ration produced a length increase to September 3rd of 21.3 mm. C. of V. —27.2% with a mortality of seventy-five individuals, whereas the frozen salmon offal-canned salmon-halibut meal diet resulted in a length increase of only 11.6 mm. C. of V. —40.5% and a heavy loss of 434 fry.

One significant point in a consideration of the season's results is the relative length increases provided by the several rations. During the first month of feeding, represented by the first two steps in the

diagram, beef liver, Lot 1, produced a much greater length increase than any other ration and was improved upon for low mortality counts by only one other ration, Lot 8 (canned salmon —50 + beef liver —50). During the next four weeks' development, third and fourth steps, beef liver —100 lost headway and was equalled, if not excelled, by a number of other rations. In the concluding two periods beef liver again indicated its importance but outstanding increases were made by Lot 15 (frozen salmon offal-canned salmon-halibut meal), Lot 11 (halibut meal —75 + beef liver —25), Lot 8 (canned salmon —50 + beef liver —50) and Lot 4 (frozen salmon offal —50 + beef liver —50).

The knowledge gained in 1930 of the value of beef liver in the diet of sockeye salmon fry, of its effect particularly in the early stages of feeding and of the possibility of using a mixed ration of beef liver and some other cheap substitute food let to further feeding experiments in 1931 and 1932, directed toward a further elucidation of these points.

If any array of the results of the various rations used in 1931 and 1932 were prepared on the basis of actual total increase in length a very illuminating distribution would be found, but since under the circumstances of the experiment a statistical interpretation thereof is necessitated, too serious reliance upon such tabulation would be difficult to justify. Without, then, maintaining too precise an adherence to an orderly arrangement of the mean length increases derived, the following list of rations, grouped in order of relative merit, may be briefly reviewed:

Year	Lot	Ration	Length Increase mm.	S. D. mm.	C. of V.	Loss %
1931	29	B.L. — 50 + D.S.E. — 50	37.9	6.7	17.7	2
1932	41	do.	33.3	4.8	14.4	8
1931	20	B.L. —100, 1st mo.				
		B.L. — 50 + H.M — 50, 2nd mo.				
		B.L. — 33 + C.S. — 33 + H.M. —33, 3rd mo.	33.9	5.5	16.2	1
1932	44	do.	30.1	3.8	12.6	2
1931	16	B.L. —100	30.1	5.2	17.3	1
1932	40	do.	30.7	3.0	9.7	2
1931	22	B.L. — 50 + H.M. — 50	36.5	5.2	14.3	2
1932	42	do.	27.5	4.5	16.4	4
1931	33	B.L. — 50 D.S.M.— 50	32.9	4.2	12.7	3
1932	46	do.	29.8	2.5	8.4	4
1931	24	B.L. — 33 + C.S. — 33 + H.M. — 33	37.7	4.6	12.2	2
1932	43	do.	25.4	4.8	19.0	14
1931	18	B.L. —100, 1st mo.				
		B.L. — 50 + H.M. — 50, 2nd mo.				
		H.M. —100, 3rd mo.	29.5	5.4	18.3	1
1931	25	B.L. — 50 + F.S.E. — 50	36.6	7.9	21.6	3
1931	19	B.L. —100, 1st mo.				
		B.L. — 50 + C.S. — 50, 2nd mo.				
		B.L. — 33 + C.S. — 33 + H.M. —33, 3rd mo.	32.3	7.7	23.8	1
1932	45	do.	27.7	5.0	18.0	2
1931	21	B.L. — 50 + C.S. — 50	34.9	4.4	12.6	1
1932	47	do.	20.4	5.7	28.0	4
1931	17	B.L. —100, 1st mo.				
		B.L. — 50 + C.S. — 50, 2nd mo.				
		C.S. —100, 3rd mo.	32.3	4.6	14.2	2

The control samples of 1931 and 1932 subsisting on a single diet of raw beef liver showed a length increase of from 30 to 31 mm. with a coefficient of variation under 20% and a loss of not more than 2%. Losses were slight, therefore, and growth relatively rapid, yet uniform. The 1932 values are much better than those for 1931, for no explainable reason. In comparison with these control values it will be at once noted that the mixed ration of beef liver —50 + dried salmon eggs —50 was in both years equal to if not superior to the beef liver ration. Similarly the growth rates evaluated for mixed rations in which halibut meal (Lots 22 and 42), dried skim milk (Lots 33 and 46) and fresh salmon eggs (Lot 25) constituted 50% of the ration indicated that these substitute foods were relatively as good as raw beef liver for 50% of the diet. The substitution of canned salmon for 50% beef liver may be equally good but the results obtained (Lots 21 and 47) are not wholly convincing. Similarly the ration made up of 1/3 beef liver + 1/3 canned salmon + 1/3 halibut meal (Lots 24 and 43) produced confusing returns, achieving relatively excellent results in 1931 and relatively poor ones in 1932. This ration would, however, bear further consideration.

In order to determine and demonstrate further the effect and importance of beef liver in sockeye salmon food rations, the following mixtures were prepared and fed. In the tabulations there are given, for comparison, the results obtained with the beef liver combination.

Year	Lot	Ration	Length Increase mm.	S. D. mm.	C. of V.	Loss %
1931	29	B.L. — 75 + D.S.E. — 50	37.9	6.7	17.7	2
	30	C.S. — 50 + D.S.E. — 50	32.1	3.5	10.9	10
	31	C.S. — 75 + D.S.E. — 25	31.0	6.3	20.3	10
	32	H.M. — 50 + D.S.E. — 50	31.1	4.9	15.7	18
	33	B.L. — 50 + D.S.M. — 50	32.9	4.2	12.7	3
	34	C.S. — 50 + D.S.M. — 50	25.3	4.0	15.8	10
	35	C.S. — 75 + D.S.M. — 25	24.1	5.5	22.8	11
	36	H.M. — 50 + D.S.M. — 50	17.0	7.9	46.5	29
	25	B.L. — 50 + F.S.E. — 50	36.6	7.9	21.6	3
	26	C.S. — 50 + F.S.E. — 50	22.5	7.9	35.1	14
	27	C.S. — 75 + F.S.E. — 25	17.7	9.5	53.7	16
	28	H.M. — 50 + F.S.E. — 50	18.7	9.2	49.2	24
	37	H.M. — 33 + D.S.E. — 33 + D.S.M.— 33	32.5	5.9	18.2	17
1932	55	He.M.— 30 + D.S.M. — 20 + D.S.E.— 20 + B.L. — 20, for 1st mo.				
		He.M.— 25 + D.S.M. — 25 + D.S.E.— 25 + C.S. — 25, for 2nd mo.	29.2	8.2	28.1	19

The total length increases and mortality figures clearly portray the effects of the several rations and render obvious the benefit derived from the beef liver. Whether the rations are deficient in nutritive value or are not of the proper physical consistency has not been determined. The canned salmon + dried salmon egg mixtures (Lots 30 and 31) and the halibut meal + dried salmon egg mixture (Lot 32) produced a fairly uniform length increase but the relative variations in the samples fluctuated appreciably and mortality figures

varied. It might be presumed that the halibut meal + dried skim milk ration (Lot 36) would not possess a very promising physical consistency and possibly this factor was responsible for the retarded development, particularly as the fry grew larger.

One other ration lacking beef liver is worthy of note, that consisting of halibut meal —33 + dried salmon eggs —33 + dried skim milk —33 (Lot 37), from which a length increase of 32.5 mm. was obtained with a loss of 17%. Mortality is relatively high but most of this occurred during the second month and during the last month of the experiment the losses were slight while the length increase was rapid.

A glance at Figure 1 will suffice to demonstrate the inadequacy of Lots 48 and 54 as suitable rations for sockeye salmon fry. Lots 48 and 49 were prepared foods on the market as desirable fry foods but both were found distinctly poor. Lots 50 and 54 were mixed rations prepared with common, easily procurable ingredients but they were likewise unsuitable. Lot 55 was the best of these latter mixtures but while, with a 30% beef liver content, it produced a high rate of growth, the subsequent development was unsatisfactory and mortality was relatively high.

In summing up the results reported above, certain conclusions seem justified but they are, of course, subject to revision where definite differing environmental factors come into play. For example, it may be reported that in these experiments halibut meal produced a very unsatisfactory growth and high mortality. In certain areas of British Columbia, however, it has been apparently productive of excellent results. An analysis of the latter situation shows that, there, black fly larvae and other natural aquatic organisms are very abundant. To this abundance of natural food, then, may be attributed the excellent development obtained. The halibut meal probably made up but a small part of the consumable food ration. In such situations, therefore, completely different sets of conditions prevail and entirely different interpretations must be placed upon the artificial food requirements.

The conclusions derived from this food study may be briefly summarized:

1. Raw beef liver possesses certain valuable properties which make it peculiarly adaptable as an artificial food ration for sockeye salmon fry. It produces excellent and uniform growth and entails little mortality.

2. While a single ration of beef liver is acceptable, substitutes may be used provided that the beef liver content is not less than 33%. In the tests these substances were frozen salmon offal, canned salmon, fresh salmon eggs, dried salmon eggs, dried skim milk and halibut meal.

3. An analysis of the relative positions of the points on the coefficient of variation chart will indicate that high percentages of variation occur for rations where beef liver is absent and, conversely, where beef liver

is included in the mixed rations, the percentages of variation are low. A beneficial reaction toward beef liver would thus be further emphasized.

4. Possible acceptable non-beef liver rations were:

canned salmon —50 + dried salmon eggs —50 (Lot 30)
canned salmon —75 + dried salmon eggs —25 (Lot 31)
halibut meal —50 + dried salmon eggs —50 (Lot 32)
halibut meal —33 + dried salmon eggs —33 + dried skim milk —33 (Lot 37)

These rations would bear further trial.

5. It has not been definitely established that the practice of feeding beef liver as a single diet during the early stages and using a substitute food substance in increasing proportion as the fish advanced in development has any appreciable merit. The method should not be discarded, therefore, since under practical, large scale pond rearing operations it would appear to have some significant productive value.

Fig. 1. General view of brook trout spawning grounds, Baldwin Creek There were six identifiable redds within the large cleared area at the center. Smaller areas of gravel cleaned of muck deposits by the trout may be seen at right of the photograph.

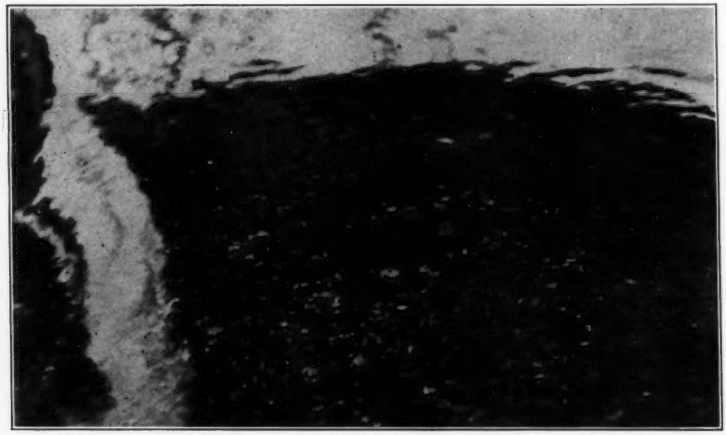

Fig. 2. A brook trout spawning pit which has been completely excavated, ready to receive the eggs, Little Beaver Creek. The deepest part of the excavation is indicated by arrow.

UNIV. OF MICH.

THE SPAWNING HABITS OF BROOK, BROWN AND RAINBOW TROUT, AND THE PROBLEM OF EGG PREDATORS

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The problem of the success of natural reproduction of trout is one of considerable interest to the fisheries investigator. The question of destruction of trout eggs by various enemies, conspicuously the sucker and other so-called "coarse fishes," has often been discussed before this Society. Incontrovertible evidence, from stomach examinations, has shown that the common sucker and the bullhead do devour lake trout eggs (Atkinson, 1931; Greene, Hunter and Senning, 1932). The presence of common suckers on brook trout spawning beds at night has been recorded (Barbour, 1930).*

During the fall and spring of two years, 1930-31 and 1931-32, the writer carried on a field study of the spawning behavior and spawning conditions of trout in some streams of western Michigan (Lake, Osceola and Manistee counties) for the purpose of determining the severity of destruction of trout eggs by natural enemies. This work was done at the request of the Department of Conservation.

The first step in this investigation was to determine how trout, of each of the three stream species of the region, carry on their reproductive activities. No accurate evaluation of the detriment to trout that may be caused by egg eaters can be made without knowing, with exactness, how the spawning takes place. Many hours were spent in observing the breeding behavior of the wild trout under natural conditions. Meanwhile particular attention was given to the behavior of any possible egg predators.

The reason for pursuing this method of study, rather than the stomach examination method, is that the finding of eggs in a stomach does not prove to be evidence of an act destructive to trout reproduction. This point will be discussed later.

Although it was not possible to carry on the investigation in streams representative of all regions of the state, records were made at eight different spawning places, streams of the Pere Marquette, Saubel, Little Manistee and Manistee drainage basins. Since common suckers, and other possible spawn eaters, are present in each of these stream systems it was thought that the sample would include some streams subject to heavy egg predatism, provided this existed.

Brook trout (*Salvelinus f. fontinalis*) were studied on the following

*Mr. Barbour's paper does not make clear what species of trout and sucker were involved but he has written me identifying the fish as *Salvelinus fontinalis* and *Catostomus commersonnii*.

days: November 12 and 13, 1930; October 24, November 3, 4, 5, 7, 8, 24, and 25, 1931; and December 5 and 6, 1931. Brown trout (*Salmo fario*) were studied November 12 and 13, 1930; November 4, 5, 8, 24 and 25, 1931; and December 6, 1931. Rainbow trout (*Salmo gairdnerii irideus*) were studied April 9-19 (inclusive), 1931; May 2 and 3, 1931, and April 23, 1932. The rainbow trout (steelhead trout) represented the Lake Michigan population, which ascends streams of western Michigan during the spawning run. The brook and brown trout were stream-resident fish.

Mr. Gerald McCrimmon, who was engaged in tagging trout during the fall of 1930 and 1931 for studies of trout migration being carried on by the Institute for Fisheries Research, cooperated in the investigation of predators. Prof. T. L. Hankinson, of Ypsilanti Normal School, contributed the photographs used as illustrations.

The Spawning Habits of Trout

The salmons and trouts are nest-building species, which spawn in gravel nests, commonly termed redds. While much has been published about trout reproduction (particularly the work of Kendall, 1929, and White, 1930, on brook trout, Malloch, 1910, on brown trout, and Seagle, 1897, on rainbow trout), there yet remain many facts to be learned concerning the breeding behavior of any species of trout or salmon. The observations of the present writer have been in agreement with several published statements regarding the processes of nest building and nest defense but have not agreed with any descriptions of the spawning act, the most critical point in the breeding behavior, from the standpoint of an investigation of egg predators.

The brook and brown trout spawning grounds were all located in spring streams, near sources of spring water. At two streams, Baldwin creek and Sandborn creek, both species were using the same spawning places at the same time. The factors governing the spawning places of brown trout are evidently in rather close agreement with those discussed for the brook trout by White (1930). The rainbow trout grounds ranged from headwater spring streams such as Baldwin creek, previously mentioned to be used in fall by brook and brown trout, to large, lower-course streams such as the Manistee river below Wellston. The river here becomes too warm for trout in summer, the water being remote from its spring-water sources. All spawning grounds were alike in having gravel present.

Each of the three species of trout has a long spawning season at any one locality studied. During 1931 brook trout were breeding at Baldwin creek (Lake county) during the period from October 24 to December 6, 1931. Brown trout at Sandborn creek (Lake county) were present on spawning grounds from November 4 to November 25, 1931. Rainbow trout were spawning in the Little Manistee river

(Lake county) from April 9 to April 19, 1931. The breeding period of this, and doubtless of the other two species, is longer than that indicated by the dates given. Seasonal variation is to be expected and, during the mild winter of 1931-1932 rainbow trout began reproduction by January in the Little Manistee river. On April 23, 1932, spawning fish, eggs in several stages of development, and fry which had absorbed the yolk sac were taken in this stream.

Recovery of eleven tagged brook trout (nine males and two females) at Little Beaver brook (Osceola county) showed that an individual of either sex may remain on the spawning grounds for as much as twenty-five days. A single male rainbow trout which was tagged on a spawning ground in the Little Manistee river was recovered at the same place six days later.

Individual fish vary in the time of arrival at spawning places, probably due to differences in time of maturity. At Little Beaver creek, during November, 1930, after the greater proportion of the brook trout in this small stream had been marked by tagging and no unmarked fish could be taken for a few days, there soon came a heavy run of new individuals, of both sexes.

At any one spawning place there were more males than females to be seen. The explanation of this fact is attributed, in part, to a younger average maturity of the males and in part to a difference in behavior. Females were rarely seen unless actually engaged in nesting activities. Males, on the other hand, frequently remained for long periods in the shallow water of the spawning places or swam boldly about, as though in search of females. The activity of males results, in many cases, in the clearing of sediment from large areas of gravel. The digging of a spawning pit is exclusively a phase of female behavior, however.

Trout spend many hours in construction of a redd and only a few seconds in spawning therein. Even when the most active redds were selected for study, a single observed spawning per day of field work was more than could usually be expected. While scores of brook and rainbow trout redds and dozens of brown trout redds were seen, the spawning of brown trout was observed but once, of brook trout but twice, and of rainbow trout but seven times.

The hours of greatest activity were found to fall within the daylight period. The single observed spawning of brown trout took place at 1.45 P. M. Brook trout records, of spawning or of early stages in redd covering, fell between 11.30 A. M. and 4.45 P. M. (six records). Both of these species were more active during the mid-day period when the light was bright than in the early morning and late evening. The rainbow trout was found to be the direct opposite in that their redds were deserted during the mid-day period, on all days of bright sunlight. Rainbow trout spawning observations were as follows: 10.30 A. M. (one record) and 4.30 to 6.45 P. M. (six records).

In view of published statements regarding the presence of egg eaters on trout beds at night (Atkinson, 1931; Greene, Hunter and Senning, 1932; Barbour, 1930), it was thought desirable to determine whether spawning took place at night in these Michigan streams. Several night visits were made to brook and rainbow trout redds which had been used by fish during the preceding daylight period. Although brook trout were seen under shelter of logs near the spawning areas, none was observed on redds during a visit to the Baldwin creek beds from 9 to 11 P. M. on November 3, 1931. Attempts to find rainbow trout working redds where they were seen by day failed to produce evidence of fish, at the Little Manistee river on two evenings in April, 1931. Marked redds of all three species failed to show evidence of night activity since no change occurred at these during the period between late afternoon and the following morning. Evidently digging of redds had not been continued during the night. Rainbow trout females which have spawned during the period just before dusk evidently remain on redds part, if not all, of the hours of darkness.

For purposes of the study of the relations of egg predators to trout, the very complex behavior of trout, of the three species, may be summarized:

A. Behavior preceding spawning: The female selects a place where there is gravel and digs a deep pit by repeated use of the tail. In digging the fish turns on one side and strikes the tail rapidly downward against, or close to the gravel. Sometimes as much as two days are spent in digging a redd. Interruptions occur, with frequent desertions. The finished pit varies in size according to species and size of female, current conditions, and type of bottom. Brown and rainbow trout spawning pits are, on the average, larger than those of brook trout, the difference being partly due to size of females. In all instances the hollow which was constructed was longer than the female making it and deeper than the greatest body depth of this fish.

Nearby males are quickly attracted to females engaged in digging. One male, of brook or brown trout, attends a female, and stations himself just downstream of her. He defends this position against other males except when an invading male of larger size than he succeeds in driving him away. Rainbow trout redds, in stages near the time of spawning, have two males, the larger of which permits a smaller one to occupy a position just downstream.

A long period of courtship is characteristic of the behavior before spawning takes place. A male attending a female frequently advances forward to a position close to or touching her side. Frequently this is done during an act of digging by the female and one might easily interpret the fish to be spawning. The prolonged period of digging and courtship behavior is evidently responsible for the

interpretation of the spawning act as described by several observers of brook and brown trout (Kendall, 1929; Malloch, 1910).

Both male and female trout defend the redd against other fish in the period just preceding spawning. Defense by the male, against rival males which approach from downstream or from the side, is very vigorous. Any invading fish are chased by either male or female, depending upon which part of the nest they approach. The female quickly notices and chases fish which approach from upstream, but does not seem to take notice of ones downstream of her.

B. The spawning act: A single act of spawning occurs at a single nest pit. There is a definite mating clasp that is different from any of the phases of behavior which precede spawning. The change in behavior of the female immediately after the eggs have been deposited is conspicuous.

Before spawning, the female takes a position at the bottom of the pit, with pectoral and ventral fins well spread against the stones. She remains motionless with her vent region close to the deepest part of the pit. Of brook and brown trout, the male, a larger fish than the female at all observed instances of spawning, darts to a position against one side of the female and curves his body toward hers in such a manner as to hold her against the bottom. For several seconds there is a rapid vibration of the body of the male. The spawning position of a female rainbow trout is similar to that described for those of the other species except that, upon coming into position, a female rainbow trout opens the mouth.*

The two rainbow trout males, one slightly larger than the female, and the other typically a younger, smaller male not so large as either fish, quickly take positions, one at either side of the female. As they come into place, with fins spread against the bottom, they open their mouths. Both are seen to be tightly wedged against the female, the tails of the grouped fish being in close contact. The force of the current, acting against the open mouth of each male, is transmitted into a strong pressure against the sides of the female as the three fish remain motionless for approximately five to eight seconds. An appreciable cloudiness of the water, doubtless caused by milt from the males, was noted at one nest. Although eggs could not be seen when deposited at any of the trout redds, their presence was verified by excavation of the exact spot where spawning was noted.

The number of eggs deposited at a single spawning at two brook trout redds dug out immediately after the spawning was forty and seventy-nine, respectively. A single brown trout redd gave a count

*Experiments with a freshly-killed female proved that the open mouth was of aid in permitting the fish to stay in the spawning position, since the open mouth increased the current resistance of the normally streamlined body of the fish. The fins being spread, prevent downstream slipping so that the current-thrust which acts against the open mouth wedges the fish into a firm position. This was duplicated with the dead specimen, which remained in position indefinitely, provided the mouth was wedged open.

of thirty-eight eggs. A single count at a rainbow trout redd, the highest of several other counts not given because of uncertain accuracy, was 855 eggs. Only by digging with a sharp-edged implement, such as a shovel, and by lifting the eggs and gravel well, before shaking into a net held below, could the entire number of eggs be secured. Attempts to dig out eggs with the hands were unsuccessful, for the gravel was disturbed in a manner such as to allow eggs to sink deeply into crevices between the rounded stones.

All of the eggs fall amid large gravel or even large stones as much as four inches in diameter, at a limited area of the nest bottom, which is from two to over twelve inches below the level of the normal stream bottom. Evidently only a few escape from the pit and are carried downstream.

C. Behavior following spawning: Immediately after spawning, a female commences to cover the eggs with gravel. Brook trout females begin to do this by a slow and rhythmic swinging of the body from side to side, as if swimming slowly, but with a greater sweep of body than used in normal swimming. The tail and anal fin are pressed against the gravel and effectively move loose pebbles inward toward the center of the pit. The eggs are soon entirely covered with coarse gravel. After a half hour or more of this behavior, females were noted to begin digging at an area a few inches upstream of the eggs. The fine gravel thus stirred up is deposited over the redd by the current. Brown and rainbow trout females begin to cover eggs by rapidly digging with the tail, moving the loose, coarse gravel of the bottom just upstream of the eggs. After a large amount of gravel has been piled on the eggs, the fish use the tail and anal fins in a sweeping process which is much like but less pronounced than that used by brook trout females in beginning to cover eggs.

Male defense lasts only through early stages of egg covering. By the time males desert, which they do within about five minutes of the time of spawning, an effective but unfinished coating of gravel has been placed over the eggs. The absence of the male exposes the area downstream of the nest to invasion by other fish. The female, however, throughout the long period of egg covering (a process continued for one to several hours) resents the presence of any fish at or just above the spot where the eggs lie.

A female remains for several hours or more at the former spawning pit, which is finally so covered as to be indistinguishable, the eggs being overlain by one and a half to over eight inches of gravel. Coarse gravel immediately surrounds the eggs while finer gravel usually forms an outer coat, especially in brook trout redds.

Both males and females participate in several mating acts before becoming entirely finished with the reproductive activities of a single season. Partially spent females and males were dissected. The dissection of several males showed that the anterior lobe of the

testis was later in maturing than the posterior lobe. Several partially spent female brook and rainbow trout, identifiable as individuals, dug redds just upstream of their first ones.

Waste Eggs and Non-Waste Eggs

Any eaters of trout spawn must get the eggs by one or more of the following means: (1) by rushing in and securing eggs at the moment of deposition; (2) by digging out eggs after they have been covered; (3) by taking stray eggs which are not within a redd pit.

There are normally a few eggs at a spawning which fail to lodge in the cup of the redd and escape, being carried downstream by the current. Although such eggs could not be seen, the behavior of fish, attracted by this source of food, showed the presence of stray eggs. At three brook trout redds, small brook trout picked up one to several objects just downstream of the point where spawning had occurred a few minutes before. The small percentage of eggs which escape from the redd during spawning or early stages of egg covering may be termed waste eggs. Unprotected from light and mechanical injury, they are obviously of no value to the species. The eating of such eggs is to be regarded as harmless scavenging.

Trout of all three species were seen to dig redds on or near the exact spot previously used by other individuals. While virtually impossible to observe, because of the difficulty of seeing the eggs, there is a strong probability that some eggs are dug out of the older redds by the builders of new ones. The percentage dislodged by this accidental means is not large on the spawning grounds studied. This occurrence, however, doubtless adds to the number of waste eggs available to egg eaters. Pacific salmons are known to dislodge large numbers of eggs from the gravels (Gilbert and Rich, 1927, p. 20, 28).

Stomach examination as a means for investigation of egg predators has a weak point in that, by this method alone, one cannot interpret the circumstances under which the eggs have been taken. If a supposed predator is eating only waste eggs, he cannot be considered to be doing harm to the trout. If, however, the eggs are non-waste, viable eggs, a possibility of damage has been proven. The study of whether or not serious damage exists is then in order. This will involve quantitative studies, for it is the number remaining that is important, not the number eaten. Even in the event that a large percentage of the total number of viable eggs were to be destroyed, it is possible that enough might remain to produce a number of young sufficient for the carrying capacity of the waters concerned.

Evidences of Egg Eating

Observations indicated that several species of fishes seemed to get a few trout eggs. Stomach examinations of certain specimens taken near trout redds supported this evidence.

Muddlers (*Cottus cognatus and Cottus bairdii*): These small fishes, particularly *Cottus cognatus*, were present in nearly all of the streams studied. Single individuals were seen near several brook and rainbow trout redds. They evidently make attempts to get trout eggs, for they were sometimes seen to dart in toward the place where a female brook or rainbow trout was engaged in the process of covering eggs. At two brook trout redds and one rainbow trout redd, the invader was immediately discovered and pursued by the female. In no instance was eating of eggs observed. A single specimen of *C. cognatus*, however, which was secured from a brook trout redd proved to have a single trout egg in its stomach. This was probably a stray egg or else an egg stolen before covering had been completed. Although muddlers will dig under stones, it hardly seems likely that they can dig deeply enough to secure trout eggs after these are completely covered.

Common sucker (*Catostomus commersonnii*): Surprisingly few suckers were seen about the spawning grounds of the trout. A single one, not over eight inches long, was seen at a rainbow trout redd on the Little Manistee river. Several were noted in deep pools on this river and on Baldwin creek near the riffles used by spawning rainbow trout. Probably the one sucker observed at the rainbow trout redd, mentioned previously, succeeded in finding one trout egg, for he swam slowly about just below the place where spawning had been observed a few minutes before, stopped and apparently ate something from the bottom, and then swam out of view. Obviously, if this fish did find an egg it was a stray one.

Brook trout (*Salvelinus fontinalis*): Small, mature males of brook trout were numerous on the Baldwin creek and Little Beaver creek grounds. Such individuals were the most abundant of the egg eaters. At three different redds the visits of one or more brook trout took place just after spawning had occurred. Searching the gravel just below a redd, and picking up one to several objects invisible to the observer, these fish apparently secured a few stray eggs. Several attempts to rush to the position occupied by the female covering eggs were immediately resented by this fish. A few brook trout eggs found in stomachs of three trout, taken at random from Little Beaver creek, supported the interpretation of this species as an egg eater. Large numbers of brook trout eggs in trout stomachs have been recorded (White, 1930).

Brown trout (*Salmo fario*): It is probable that the smaller brown trout may be successful in picking up a few of the eggs of their own species, under circumstances similar to those described for brook

trout. Several brown trout, seven to nine inches in length, taken from the Little Manistee river during April, 1931, contained rainbow trout eggs. Small trout were noted, upon several occasions, just below rainbow trout redds.

Rainbow trout (*Salmo gairdnerii irideus*): The most numerous of the possible egg eaters seen around rainbow trout redds on the Little Manistee river were juvenile rainbow trout of six to eight inches. One of these was seen to rush in during the spawning clasp of a trio of rainbow trout and he had opportunity, and doubtless made use of this, to take one mouthful of eggs before being chased by the male nearest him. Since 855 eggs were discovered in the pit of this redd, the greatest possible number that could have been stolen by this fish was a very small percentage of the number which were successfully buried by the female. The chasing of small rainbows which attempted to reach the position occupied by a female which had recently spawned was frequently seen. Search of the area below the nest was not prevented by female rainbow trout and the eating of a few objects presumed to be eggs took place here at the majority of the redds where spawning was seen. Metzelaar (1929) found rainbow trout eggs to be frequently eaten by the same species.

Miscellaneous: Although horned dace were present in several of the streams, they were not seen near trout redds. Black-nosed dace, and several other small species which were present in certain of the streams, have too small a mouth to allow them to feed upon trout eggs. No egg predators other than fishes were seen. While one might suppose that the large numbers of breeding trout that were present (as many as seventy-five brook trout were seen from one observation point at one time) would attract various fish eaters, evidence of any concentration of these was lacking. The spawning season of trout does not coincide with the season of greatest abundance of fish-eating birds, although the American merganser, osprey, kingfisher, and great blue heron were among the birds seen during the April studies. Mergansers and other birds are known to feed upon eggs of Pacific salmons when large numbers are available (Munro, 1923).

SUMMARY

(1) The relation of the common sucker and other possible predators of trout eggs to trout reproduction was studied by field observations in some western Michigan streams used as spawning grounds. The breeding behavior of brook, brown, and rainbow trout was studied.

(2) Female trout construct a pit and deposit eggs at the bottom of this, among coarse gravel or even large stones, during a single act of spawning. One male brook or brown trout mates with one female. Rainbow trout spawn in trios, one male being firmly pressed against each side of the female while the eggs are being deposited. The nesting

process is repeated several times before all of the eggs contained by one female have been deposited.

(3) Immediately after spawning, female trout cover the eggs with a thick coating of gravel. Defense by the male is continued during the early stages of nest covering while the female defends the redd for several hours after spawning.

(4) Attempts of trout and muddlers to take eggs from the pit were successfully prevented by female trout in the majority of observed instances. At most, a very slight percentage of the eggs deposited in the pit are taken in the interval between spawning and covering of the eggs. No attempts to dig out and feed upon eggs in the finished, covered redds were seen. By the time the female trout desert the eggs these are so well covered by gravel that disturbance by predators is unlikely.

(5) Waste eggs are common, due to the fact that some eggs fail to lodge in the pit and because female trout often dig redds at areas previously used by other trout. The percentage of eggs which are loose in the stream rather than firmly lodged in covered redds is not large. The numbers are sufficient, however, to be sought by egg-eating fishes, notably the muddler, common sucker, brook trout, brown trout, and rainbow trout.

(6) Since eggs which are loose in the stream are unprotected from light and mechanical injury they are to be regarded as waste eggs, the destruction of which cannot be harmful to trout reproduction. Trout eggs in stomachs are not sufficient evidence for proof of acts harmful to reproduction.

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FURUNCULOSIS ON THE PACIFIC COAST

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Introduction

The disease of food and game fishes known as Furunculosis has recently become a factor of increasing economic importance both in Europe and on this continent. Since its original description in Germany in 1894, this epidemic or more properly epizootic disease has been recorded in other parts of Germany, in France, Switzerland, in many parts of the British Isles, and in the eastern and mid-western portions of North America. The serious nature of the disease is well attested by the formation, in 1929, of a Furunculosis Committee by the Ministry of Agriculture and Fisheries of Great Britain. This body was formed "to investigate the origin, predisposing causes and mode of dissemination of Furunculosis and similar infectious diseases among salmon, trout and other fresh water fish in England and Scotland, and to conduct experiments with a view to ascertaining methods of combating the disease. . . ."

The Interim Report of this Committee (1930) gives an adequate review of the literature of the subject to the date of publication, as well as a record of original work. No attempt will therefore be made in the present communication to give reference to all of the many publications on Furunculosis. Thirty-one papers are referred to in the Committee's report, and other works have since been produced. Among the newer publications should be mentioned those of Blake (1931), and of immediate interest on this continent, that of Stevens and Keil, reported in the 1931 Transactions of this Society.

According to the Interim Report of the Furunculosis Committee, the disease had by 1929 been identified among salmon and trout in eighteen different districts in Scotland and England. In a single English river, over the period 1926-1929, a total of 1,900 salmon were found dead of Furunculosis. When it is considered that this loss occurred among the escapement in the river, after commercial and sport fishing had already depleted the runs, it can be seen that the number of salmon available for spawning must have been considerably reduced by the ravages of the disease.

As has been stated, Furunculosis is prevalent over considerable areas of eastern and mid-western America. A recent personal communication from Dr. H. S. Davis indicates that the disease is known to occur in a large number of private and state brook trout hatcheries in Massachusetts, Connecticut, Vermont, New York, Virginia,

New Jersey, Iowa, Michigan, and Wisconsin. While the disease is common in these states among fish in ponds and hatcheries, it does not appear greatly to affect fish in streams.

The majority of Furunculosis outbreaks seem to have been recorded among members of the family *Salmonidae*; while different genera and species differ in susceptibility, the disease in nature is undoubtedly most common among this family. The disease has also been recorded in nature in fish of the genera *Coregonus* (by Plehn) and *Thymallus* (by Plehn, Arkwright and others), and in a few other genera (vide Interim Report Furunculosis Committee). When artificial inoculation is resorted to, a great number of fish, including some marine species and certain other cold-blooded vertebrates, are found to be susceptible in varying degree. For instance, Williamson has experimented with frogs, goldfish, minnows, trout and eels.

Further, the contagious nature of the disease has been experimentally established by Horne (1928) and Blake (1931), together with the fact that numbers of fish may become "carriers" of the disease although surviving in apparent health for considerable periods. The importance of such experimental work cannot be overestimated, as it may eventually lead to a knowledge of the ways in which the disease becomes distributed in nature.

It is the purpose of this paper to record the identification of typical Furunculosis in two districts in British Columbia, and in two genera of food fishes. So far as is known, the disease has not before been positively identified west of the Rockies, and according to the personal communication from Dr. Davis, does not seem to have been suspected before in this area.

Pathological Features

As early as 1894 Emmerich and Weibel in Germany described under the name Furunculosis an infectious disease of the *Salmonidae*. These pioneer workers further showed the causative agent of the disease to be a short, Gram negative, non-motile, non-spore-forming bacterium which they named *Bacillus salmonicida*. This organism, in addition to possessing characteristic pathogenic and biochemical properties, is able to produce a soluble brown pigment when grown upon ordinary bacteriological media.

According to David (1926) and others, the disease may exist in fish as an infection of the intestine, but is far more frequently met with in the form of an acute septicemia, in which the bacteria localize in various parts of the body, destroying the tissues and giving rise to typical lesions. Of these lesions some of the most common are liquefactive necroses (i. e., "killings") of various body tissues including kidney, spleen, dermis and muscle. The spleen and kidney may become a fluid or semifluid mass, and large areas of muscle,

usually just under the skin, may be transformed into a reddish, semi-fluid, pus-like material.

The term Furunculosis was first applied to the disease because of the apparent similarity to human boils or furuncles of the subcutaneous lesions which were often an outstanding external symptom of the disease. As has been pointed out by Arkwright, these lesions cannot really be compared to boils. Boils are characteristically suppurative, inflammatory foci, identifiable by the presence of great numbers of white blood cells or leukocytes, but in the case of the fish lesions, the red fluid material present is not true pus, but consists only of disintegrated muscular and vascular tissues, together with free blood cells and bacteria. Since death from infection by *B. salmoicida* can occur without the appearance of any exterior boil-like lesions whatever, it can be seen that the original name of the disease is somewhat of a misnomer.

A frequent external sign of the disease is the presence of reddish patches under the skin, caused by infiltration of blood among the superficial muscle fibers. Where extensive liquefaction of muscle has occurred under the skin, the lesions will frequently open to the exterior as ulcers in one or more places, and may discharge some of the pus-like fluid. Davis notes that in fingerling trout often the only evidence of a lesion seen from the outside may be a dark blotch of varying area under the skin, there being no opening to the exterior. Davis (1929) also notes a distinct tendency for superficial lesions to develop at the base of the dorsal or pelvic fin, and points out the necessity of distinguishing between such lesions and those caused by a different disease known as "fin rot." Other outstanding postmortem features are congestion of the intestinal tract (frequently of the posterior portion) and the discharge of blood and mucus from the vent.

The Interim Report of the Furunculosis Committee of Great Britain (1930) already referred to states that the occurrence of typical external lesions among victims of the disease is inconstant, as is also the condition of the internal organs. At the same time, if a sufficiently large number of fish be examined, there is usually little difficulty in obtaining a record of nearly all typical findings in a group of individuals. This is aptly illustrated by a record in the present paper (Table I) of the frequency of the different pathological findings in a large number of fish.

Elk River Investigation

In August, 1931, at the request of the Chief Supervisor of Fisheries, the writer investigated a disease among the fish of the Elk river, at Fernie, B. C., a part of the Kootenay river system. Consultation with the local fish and game club, and consideration of a report made in August, 1930, by Mr. Mottley of the Pacific Bio-

logical Station, indicated that 1931 was the third successive summer in which the disease had appeared in the river. During July and August, 1929 and 1930, many fish had been found dead, and also taken alive, bearing "abnormal red discolorations either behind the gills, around the vent, or along the sides near the dorsal fin, and having the appearance of red blisters" (Mottley). The fish reported to have been so affected were Rocky Mountain whitefish (*Prosopium williamsoni*), charr or Dolly Varden trout (*Salvelinus malma*) and an occasional cutthroat trout (*Salmo clarkii*).

In August, 1931, the greatest number of victims appeared to be Rocky Mountain whitefish. During a three-day investigation, fifteen dead or fresh-caught whitefish, one cutthroat preserved by freezing, and three fresh-caught cutthroat were examined. Ten of the whitefish were picked up dead, the remainder having been caught. A characteristic marking on all but two whitefish, which had apparently died of wounds, consisted of a hemorrhagic, roughly circular area of 1 sq. cm. or more in diameter, situated directly between the pelvic fins, and often involving the bases of the fins. Similar areas also occurred in some of the specimens on other parts of the ventral surface. In some fish the pelvic mark appeared as an open lesion, and in others simply as an area of subcutaneous hemorrhage. In the case of one whitefish, the entire ventral surface was dark red due to subcutaneous hemorrhage or infiltration. Peritoneum and omentum were heavily infiltrated in six instances, and in two cases the posterior intestine was greatly swollen and infiltrated with blood. Even in the freshest specimens the kidney had become a fluid mass. Spleen and liver lesions were not visible to the eye.

Cultures were taken upon ordinary nutrient agar from the kidney, blood vessels, and subcutaneous lesions. Such cultivations yielded, nearly always in pure culture, a short, Gram-negative, non-motile, non-spore-forming bacterium displaying a tendency to bipolar staining. A coffee-brown soluble pigment was produced in pore cultures, which diffused through the agar medium. The frozen cutthroat was not cultured, and except for a mark between the pelvic fins, yielded no definite postmorten findings. The three cutthroat caught in the same reach of the river as the whitefish showed no gross tissue changes, and cultures from kidney and heart blood proved sterile. Definite evidence of the presence of Furunculosis was thus obtained only in the case of the Rocky Mountain whitefish.

The cultures obtained were further examined by the writer and by Miss B. J. Stewart at the Department of Bacteriology, University of British Columbia, and were found to conform in all major cultural respects with *Bacillus salmonicida* Emmerich and Weibel, as described by the original and by later workers. A large number of the biochemical reactions of the organism were studied, and will be recorded in full at a later date. It is sufficient to note here that the

strains of the organism obtained from the Elk river fish fermented the carbohydrates dextrose and mannite, with the production of small and irregular amounts of gas, and that lactose and saccharose were not fermented. Gelatine was liquefied in saccate form, and the production of a diffusible brown pigment on agar was a constant characteristic. Loeffler's coagulated serum medium was completely digested in four to six days, with the production of a brown turbid fluid.

The above findings only are recorded here since they have been deemed sufficient by other writers (Interim Report Furunculosis Committee, Section 27) definitely to establish the identity of the organism.

Goldfish were inoculated subcutaneously and intramuscularly with suspensions of the bacterium. A number of these fish died, showing subcutaneous hemorrhage and visceral congestion, and the bacterium was recovered in pure culture from the kidney in all cases. These findings would appear to demonstrate conclusively that the disease found in the Elk river was truly Furunculosis.

Cultus Lake Hatchery Investigation

The second outbreak of the epizootic in British Columbia was noted among hybrid individuals of the Pacific salmon (*Oncorhynchus*), approximately 3,000 of which were contained in a large wooden retaining pond at the Smith Falls Hatchery of the Pacific Salmon Research Station, Cultus lake, B. C. This lake drains through a stream into the Vedder river, which in turn connects with the Fraser river. The fish were crosses of sockeye (*Oncorhynchus nerka*) and chum (*O. keta*) salmon and were three years old. During the summer months of 1932 daily losses of from one to two up to seven or eight fish occurred. Postmortems and bacteriological examinations were performed on 103 of these fish, this number representing the majority of fish which died between July 5th and August 19th, 1932. *Bacillus salmonicida* was recovered from kidney and muscle lesions in ninety-four cases. In eighty cases the bacterium was recovered in pure culture, and in the remaining fourteen instances the organism was present but mixed with other bacteria apparently belonging to the soil and water groups.

In view of the fact that the drainage from the infected pond emptied directly into Cultus lake, a bacterial examination was made of the kidneys of two suckers (*Catostomus macrocheilus*), seven squawfish (*Ptychocheilus oregonensis*), and three Dolly Varden trout (*Salvelinus malma*), caught by net on July 29th, and from seven Dolly Varden trout and three suckers, taken also by net, on August 25th. *B. salmonicida* could not be detected in any of these kidneys, all but three of which were sterile.

The strains of *B. salmonicida* thus isolated from the fish of the

Cultus lake retaining pond have not as yet been compared in all particulars with the strains from the Elk river, either biochemically or immunologically. However, the Cultus strains ferment dextross and mannite, with the production of very small amounts of gas, and fail to ferment lactose and saccharose. Liquefaction of gelatin is of the saccate type, and Loeffler's serum medium is digested with the production of a brown color. With the exception that the amount of gas produced by fermentation of dextrose and lactose is slightly smaller and more regular in volume in the Cultus strains than in the Elk strains, no difference can be noted between the strains as regards the characteristics listed. Intensity of pigment production was found to vary somewhat among individual cultures of the organism taken from different fish, so that it is difficult to compare the strains from the two localities as regards this characteristic.

The pathological features of the disease were recorded in detail at the time of examination. A statement of the frequency of occurrence of the major types of lesion is given in Table I. A few lesions, differing in location and character from those recorded here, appeared in a small number of the fish examined; those listed in the table were found to be the most common of occurrence.

It will be seen that the most common feature was the presence of one or more of the various kinds of muscle lesion, while necrosis of the kidney, intestinal congestion, disintegration of spleen and bloody exudate from the vent follow in order of frequency.

Infection experiments have not yet been carried out with the Cultus strains of the organism, nor have either the Elk or Cultus strains been compared immunologically with other known strains. The exceedingly close correspondence, however, of the pathological findings with those given in the literature for Furunculosis, together with the results of the bacteriological studies already made, do not seem to leave room for doubt that the epizootic in the Cultus lake pond was due to this disease.

TABLE I

Total Number of Fish Examined—103

PATHOLOGICAL FEATURE (naked eye observation only)		FREQUENCY OF OCCURRENCE
Muscle—Large (0.5 to 8 cm.) closed lesions containing fluid or semifluid, reddish "pus," subcutaneous or deep	27	Number of fish showing one or more of the three types of muscle lesion—66.
Muscle—Large lesions open to exterior through one or more ulcers, but not located at base of pectoral or pelvic fins	10	
Muscle—Small hemorrhagic dots or streaks in	41	
Kidney—Liquefactive necrosis of	62	
Spleen—Liquefactive necrosis of	57	
Liver—Hemorrhage or lesions of	25	
Vent—Exudate of blood and mucus from	50	
Intestine—Congestion of any portion of	61	
Intestine—Marked congestion of posterior part, with or without congestion of other portions	43	
Pelvic fins—Subcutaneous hemorrhage or lesion at base of	40	
Pectoral fins—Subcutaneous hemorrhage or lesion at base of	33	
Anal fin—Subcutaneous hemorrhage at base of	22	

No explanation can at present be given as to how this economically important disease gained a footing in the districts mentioned.

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A PROPOSED METHOD OF RECORDING FISH GROWTH AND GRADING WATERS FOR STOCKING

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During the past twenty years the biological survey of inland waters has become an important part of fish conservation. Methods have become more or less standardized and numerous surveys ranging from superficial examinations to the carefully organized and elaborate investigations of New York state have been conducted in connection with stocking programs.

The determination of the value of a body of water for stocking, depends ultimately upon the judgment of the person who attempts to evaluate the collected data of a survey. In most instances the data upon which his opinion is based have been collected during a fractional part of a year and represent a cross-section and not a complete study of the body of water. Even when complete data are available, practical experience may later prove that the estimate in respect to species, growth, and number is erroneous. Nevertheless, the failure of the personal equation in no way detracts from the importance of such biological survey work. The greater the advance along this line of investigation, the greater will be the ultimate gain in the practical application of scientific knowledge.

Since it will require years to bridge the present gap between the biological survey and the final establishment of correct standards for stocking, any additional aid in classifying waters for stocking purposes should prove useful. We propose a tentative method, based on the rapidity of fish growth, which may supplement the work of the biological survey and may prove of practical value in grading waters.

The determination of the average size of the age groups of a species would give a record of its growth in a particular body of water. Obviously this would require large collections of fishes and elaborate scale readings. The proposed method, which requires only scale and length measurements on a relatively small number of specimens, is presented for the purpose of stimulating further studies along this line by fish morphologists.

In studying the growth of salmon parr in their native rivers a series of measurements of the scales was made in order to determine the relationship between the size of the scale and the length of the fish. It was found that the growth of the scale in the average parr was practically proportional to the increase in length of the fish subsequent to the start of scale formation. When the size of the scale is plotted against the length of the fish for the average parr of

different ages, the resulting curve is so slight that deviation from a straight line is only noticeable in the case of the largest parr.

When salmon parr of the same ages were separated into groups according to length, it was found that the shorter or slow-growing parr had proportionally larger scales than the average parr, and correspondingly that the longer or rapid-growing parr had proportionally smaller scales. This is evidently a general phenomenon not limited to any one species. Van Oosten called attention to this point in his study of the lake herring, and the writer has been informed by J. A. Nesbit of the U. S. Bureau of Fisheries that it has been found in the data of several other investigators but not specifically mentioned.

Since the growth of salmon parr differs in the various rivers, it appears possible to grade these rivers in respect to the growth of parr on the basis of the ratio of scale growth to length. The general principle may hold true for the various species of trout and even for other fishes. Once standards have been established for excellent, fair, and poor growth, it may be possible by measuring the scales and lengths of 100 young fishes of specific age groups to classify the potential value of a body of water.

Water temperature, a most important factor regulating scale growth, may seriously affect the efficiency of the proposed method. In cold water the scale-length ratio is markedly lowered. Nesbit, in his unpublished investigations, has shown the greater retarding effect of low temperature upon the growth of scale than upon the growth of the fish. Consequently streams in which the temperature of the water during the growing period falls within the zone of retardation for any appreciable time cannot be compared with other streams not affected in this way. Careful studies along this line must be carried out before the practicability of the scale-length ratio method can be determined. However, the water temperatures of our trout streams do not show a wide range, and unless there is a marked gradation in the temperature which affects scale growth this objection may not prove of practical importance.

If care in the sampling and collection of specimens from typical parts of a stream is observed, the scale-length method of grading a stream should prove a valuable adjunct in connection with stream surveys. If it proves a reliable guide it will furnish an easy method of grading waters in respect to fish growth. However, it will not give information relative to the number of fish to be planted, the available food supply, or the chances of survival. It appears to be of sufficient importance to warrant serious consideration and thorough investigation to determine possible complications and to establish working standards.

THE PRACTICAL VALUE OF SCIENTIFIC DATA IN A STOCKING POLICY FOR OHIO

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The first attempt at fish propagation by the State of Ohio appears to have been made in 1875 through an appropriation by the legislature, for the construction and operation of four fish hatcheries near various cities along the Lake Erie shore. The purpose of these hatcheries was to hatch whitefish eggs. Apparently the greatest success was had at the Toledo hatchery, for later this one was enlarged while the others were abandoned. About 1885, attempts at propagating black bass were made on Kelley's island, Lake Erie, but met with no success, and the project was later abandoned. It was not until the opening years of the present century that black bass were successfully propagated in Ohio.

In 1892, due to continued failures at attempting to raise black bass fingerlings, and upon the recommendation of one of the Ohio Fish Commission members, Dr. James A. Henshall, the fish car "Buckeye" was purchased and put into service. This car's purpose was to transport the adult wild fish, primarily black bass, that were captured in Lake Erie, and distribute them in the waters of inland Ohio. This practice of planting Lake Erie fish in inland waters has been carried on ever since, though at present most of the fish are transported by truck.

As time went on the technic of raising fingerling bass and other game fish in hatcheries became better developed until today this phase of conservation ranks as one of the most important functions of this division of state government.

During the early period of planting fish in inland Ohio, comparatively little was known of the habits and distribution of the native fishes, and consequently these factors could not be considered in the stocking policies of that day. At that time there appeared to be a tendency to distribute from Lake Erie certain species found inland that could be taken in the greatest quantity. As the largemouth bass could be more easily hatched in the fish ponds than the smallmouth bass, it was the species distributed in the largest numbers. We today know that this indiscriminate planting of lake and stream species without regard to their environmental needs was not conducive of the best results.

In 1920, the Ohio Bureau of Fish and Game, at the suggestion of Dr. R. C. Osburn of Ohio State University, inaugurated a scientific study of all Ohio waters to collect data upon which to base a stocking policy. As this survey has been conducted almost continuously

since then by research workers of the division, a considerable amount of data has been compiled; up to the present time over 2,000 localities have been studied, some in every county and almost every township in the entire state, and many localities have been checked again and again. These data provide a good working knowledge for the distribution of our fish and the stocking of public waters. Many of the major factors controlling the distribution and numbers of each species of fish were determined, such as the physiographic features of stream valleys and chemical analysis of the waters. Particular attention was paid to the ecological relationships such as the fish associations and stressing the importance of forage fishes, temperature requirements for spawning, and destructiveness of various diseases. We can now begin to understand why some streams are fished out while others are not, and can make reasonable predictions as to the probable results of stocking certain species of fish in particular places.

The survey also brought to light some interesting facts concerning the lack of results of previous implantations of fish. For over thirty years yellow perch have been taken from Lake Erie by the thousands, in both spring and fall, and liberated in the streams of southern Ohio. During the entire survey less than twenty specimens of yellow perch were collected in these streams, and the conclusion is drawn that these fish were simply wasted from the standpoint of natural propagation in southern Ohio. It is a splendid illustration of the futility of planting a species in an unsuited environment; what may have become of these fish is an interesting question which has not been answered. We do know that the sportsmen did not catch many of them, and the most logical explanation appears to be that they migrated downstream into the Ohio river.

Thousands of adult and fingerling smallmouth and largemouth bass have been planted during the last forty years in the streams of southern Ohio, and there has been no distribution of the spotted or Kentucky bass to our knowledge; yet the survey records show that today the spotted bass, the species *not* planted, is the dominant black bass of the lowland streams of that region. The fact that this fish has been able to withstand the repeated invasions of its two closest relatives indicates the futility of stocking one species of bass in the environment of each of the other two.

Oddly enough, but comparatively little of this survey data was used for stocking purposes by the Ohio Division of Conservation during the first eleven years of its accumulation, and it was not until late in 1931 that it was given intelligent consideration. At present the knowledge gained by this survey is used to the fullest extent, and all fish are being placed only in habitats known to be suitable for their further existence. No more yellow perch are to be planted in southern Ohio streams, and no more smallmouth and largemouth bass are to be assigned to waters suitable only for spotted bass.

Heretofore, there has been no closed spring fishing season in Ohio on any species of fish except the black basses. Under normal conditions the adult fish other than bass brought inland from Lake Erie in the spring are placed in waters where they may be immediately caught out, and if the bass are planted before the closing of the season they also may be caught. Believing it to be desirable to give these fish a chance to spawn at least once, it was decided to close one-third of the unpolluted streams of Ohio to fishing for a period of two and one-half years, and to heavily stock these closed waters. On January 2nd, 1932, these streams were closed to all fishing or the taking of bait by an order of the Conservation Council upon the recommendation of the Conservation Commissioner; but because of economic reasons were opened again on July 1, 1932. Due to this additional spring protection afforded, coupled with favorable weather conditions, there has been an unusually fine hatch of wild fish. This fall the bulk of the hatchery fingerlings are to be placed in these streams also.

Formerly the hatchery and adult fish were transported by fish car or truck to some central point in a county where they were received by local sportsmen or their organizations, placed in milk cans or other such receptacles, and taken away to the streams. While the intentions of the men and organizations were creditable, yet, through improper handling, a great many fish failed to reach the water in good condition. Today the fish are entirely handled and placed directly in the portion of a stream most suited for them by state employees, who are trained in this work. The sportsmen's organizations are still notified when fish are to be planted in their vicinity and are invited to assist. A number of recent improvements in hauling fish have been made and experiments along this line are still being conducted.

To summarize, the results of the fish survey in Ohio are being utilized in 1932 for the first time and many of the errors of the past have been eliminated by this utilization. Chief among these errors was the waste of fish that accompanied the indiscriminate distribution which placed certain species of fish in waters totally unsuited for their further existence. While such obvious factors as pollution have had their detrimental effects recognized for some time, the specific habitat requirements have been up to recently overlooked or ignored.

THE AIM OF RESEARCH IN FISH CULTURE IN CANADA

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Fish culture has had for sixty-six years a very important place in the program and activities of the Department of Fisheries of Canada. It may be considered to have had its origin in 1866 with the work of Samuel Wilmott at Newcastle, Ontario, and during the succeeding fifty years, under government jurisdiction, there was built up an extensive and efficient organization for the hatching of the eggs of many species of fish.

Toward the end of this half-century of intensive artificial propagation, it became evident that fish culture involved more than the hatching of eggs and that progress could not be made on a sound basis without the adoption of a well-founded research program and the application of scientific principles. Discussions between the Department of Fisheries and the Biological Board resulted in the latter being requested to develop a research program. Accordingly, in May, 1925, a Research Committee on Fish Culture was set up under the chairmanship of Professor A. G. Huntsman. The committee accepted as its function: (1) the promulgation of scientific principles to be applied in the fish cultural work of the Department; (2) the planning of scientific investigation in reference to fish culture.

The aim of the body has been to develop a program of research that would yield information not only of immediate applicability but of fundamental value. Investigations of a rather varied character have been planned and reviewed over a period of seven years. Because of the fact that Mr. J. A. Rodd, Director of Fish Culture, is a member of the Committee on Fish Culture, a very close co-operation has resulted with the Fish Cultural Branch which has made available its hatchery equipment and personnel without which many studies would have been practically impossible.

Definition and Scope of Fish Culture

Before referring to specific researches, it appears advisable to indicate the broad view of fish culture which has been taken by the committee.

Fish culture, implying as it does cultivation, is something more than hatchery procedure. It manifestly involves the care of fish throughout the life cycle. For the development of an adequate policy, therefore, there is required as complete a knowledge as possible, (1) of the life history, structure and physiology of the fish themselves, (2) of the plants and animals inhabiting the waters and forming the

association of which the fish are a part, and (3) of the physico-chemical environment and the interrelations between it and the fish.

For purposes of discussion, fish culture may be considered under three headings which are obviously artificial but serve a purpose here:

(a) the care of fish in natural bodies of water
(b) the artificial propagation of fish
(c) the production of fish in relation to catch.

Care of Fish in Natural Bodies of Water

Theoretically the care of fish in natural bodies of water should be the first step in fish culture. Historically, this has been the case, small water areas, particularly artificial ponds, having received considerable attention. Extension to large bodies has made very slow progress for two main reasons. In the first place, the larger water areas are difficult to handle and the stock is difficult to manage. Control of water levels, silting, stagnation, pollution, obstructions in the streams, migration of fish, spawning, and fish out-take is difficult. In the second place, detailed information concerning the biology of the fish and the aquatic environment is very limited. Data concerning natural propagation, development, food requirements, growth and mortality are meagre and a census of a fish population is difficult to obtain.

While there is a tendency to neglect this phase of fish culture because of the difficulties involved, it nevertheless remains fundamentally the most important. The number of eggs deposited naturally by fish is large as compared with that which can be handled economically in hatcheries and every effort should be made to maintain adequate spawning areas, to provide ready access for the mature fish to the beds and to protect the spawning fish and the eggs. The lakes and the streams are the fields in which the crops of fish grow and more and more attention must be given to their management. There is need for more scientific knowledge and for the coordination and application of the knowledge to the production of fish in our great natural water areas.

Artificial Propagation

In view of the difficulties associated with the culture of fish under natural conditions, it is not surprising that attention should have been given so largely to that phase of fish culture referred to as artificial propagation. In this field, artificial beds (baskets) are provided for the eggs, the flow of water controlled, silt and debris eliminated, aeration assured, enemies excluded, fungus controlled. An efficient technique has been developed. With some species of fish the young are retained in ponds where they receive close attention and abundance of food.

However, artificial propagation has been open to criticism in that

it has not been based upon adeqaute scientific data. Until recently it could be said that scarcely a single operation in the whole series of procedures had been studied critically. The various methods of spawning, fertilization, and hardening of eggs; the optimum number of eggs per basket, trough or jar; the relative merits of egg, fry, fingerling, and yearling planting; the time and place for the distribution of the hatchery product had not been investigated under rigidly controlled experimental conditions. No attempt had been made to determine to what extent artificial propagation was more efficient than natural propagation. Little effective effort had been made to determine the extent to which artificial measures should be carried in relation to the problem of production in any given area. It is evident that the infiltration of the scientific method into this field of fishery biology has been rather slow. However, substantial progress is now being made and wherever possible the various steps in artificial propagation are being subjected to careful investigation.

Production in Relation to Catch

Finally a third phase of fish culture has been suggested, namely, production in relation to catch. While in a sense this might be considered as a part of the first phase, consideration of catch has become so divorced from culture that ordinarily little thought is given to the connection between them. In pond culture the relation is obvious. Catch or harvest in excess of production means depletion. It is thus the business of the fish culturist to determine the productive capacity of the pond, the reproductive capacity of the species of fish propagated, and finally to determine the annual dividend in fish. In bodies of water beyond private jurisdiction, the out-take must be controlled by governmental regulations. However, at the present time, no matter how concerned a fish culturist may be as to the maintenance of a body of water at a high level of productivity, he cannot advise, on the basis of scientifically acquired data, what annual out-take may be permitted, nor what should be the extent of his operations in relation to existing out-take.

It is realized that this problem of production and out-take is a broad biological one but it is of particular concern to the fish culturist. It is one that he must solve or have solved for him before he can adequately determine a sound policy for any species of fish. His propagation program should be based upon the productive capacity of the body of water and the extent of the fishing drain, or having determined the productive capacity to regulate the catch accordingly. At the present time the extent of fish cultural operations in relation to fishing drain is largely a matter of guess, as is also the regulation of catch in relation to production.

It will not be possible within the limits of this paper to review all the investigations in the field of fish culture being carried out by the Biological Board of Canada but references will be made to a repre-

sentative selection under the three phases of fish culture as above outlined.

Care of Fish in Natural Bodies of Water

Investigations under this head include: (a) the determination of the physical, chemical, and biological conditions existing in the waters; (b) life history studies of fish particularly but of other aquatic organisms as well; (c) an analysis of the relation between environment and the plant and animal forms; (d) a determination of the limiting factors in the development and growth of fish.

In New Brunswick, a concentrated study is being made of conditions existing in the Chamcook lakes. Three lakes occur in series and each differs from the other two in general characteristics, making possible a comparative study involving the causes of the differences and the relation of these to differences in productivity. A large scale experiment on the possibility of increasing productivity by fertilization has been undertaken in one of the lakes and at the same time a comprehensive series of experiments in the fertilization of artificial ponds has been carried out at St. Andrews.

In Manitoba, an investigation has been made of lake Winnipeg with reference to the conservation of the whitefish, cisco and sturgeon fisheries. The appearance of a rather intensive cestode infection of whitefish and ciscoes has made difficult the formulation of a fish cultural policy for this lake but at the same time has brought forward an additional interesting problem. The studies are now being continued under the auspices of the Provincial Government of Manitoba.

In Saskatchewan, the lakes and streams of the Prince Albert National Park are being investigated in order that a fish cultural policy may be developed for the park area.

In Alberta, a general survey of several lakes in Jasper Park was carried out and certain recommendations made with respect to the introduction of aquatic vegetation and certain species of fish. The results from the policy initiated are encouraging in that speckled trout up to six pounds in weight are now being taken in one lake following an introduction in 1928.

In British Columbia, a number of lakes in the central portion of the province have been investigated for the purpose of evolving a policy for the conservation of the Kamloops trout.

Life history studies of Atlantic salmon, speckled trout, shad, whitefish, sturgeon, pickerel, Kamloops trout, and Pacific salmon have been carried out and a body of detailed information is being built up.

Finally, an attack is being made on the problem of the nature of the limiting factors in the propagation and growth of fish. With many species, spawning appears to be reasonably successful, but early mortality appears to be excessively great, and frequently growth is slow and maturity delayed. Whether the defects lie in

the physical, chemical, or biological conditions, once they are determined, consideration may be given to the possibility of so modifying the conditions that production may be greatly increased. Investigations of this character have been commenced with shad and smelt on the Atlantic coast and sockeye salmon on the Pacific.

Artificial Propagation

Some of the deficiencies in knowledge with respect to artificial propagation have been pointed out. The research program of the Biological Board includes an attempt to remedy the defect as well as to determine the place of artificial propagation in the general scheme of fish culture. On the Atlantic coast a study is being made of the extent of survival of the fry and fingerlings of speckled trout when planted under various stream conditions. An analysis is being made of the conditions prevailing in a number of the hatcheries in the eastern provinces with the object of discovering those conditions which are conducive to mortality of eggs and fry. It is a case of developing a system of preventive medicine for fish. An experimental hatchery has been erected at St. Andrews and the various steps in hatchery procedure as applied to speckled trout and Atlantic salmon are being investigated.

On the Pacific coast a research station has been established on Cultus lake, in conjunction with the hatchery of the Fish Cultural Branch. Here the relative efficiencies of the natural and artificial propagation of sockeye salmon are being determined in terms of numbers of yearling seaward migrants. Investigations are being made to determine the best methods of taking, fertilizing, washing, and hardening of eggs and of the optimum capacities of baskets and troughs. In the northern part of the province, the natural propagation of pink salmon is being studied by the enumeration of adults proceeding upstream to the spawning beds and of the fry migrating seaward. With both species an attempt is being made to determine the success of transferring eggs or fry from one area to another.

Production in Relation to Catch

The only definite investigation in this field is that being conducted at Paul lake, in British Columbia. This body of water contains but one species of fish, namely, the Kamloops trout. There is a single inlet stream to the lake and into this the trout run to spawn. A hatchery is maintained by the Fish Cultural Branch on the upper portion of the stream and a trap is operated in the lower portion whereby all the fish entering the creek are captured and stripped. The number of spawning fish and their ages can thus be determined in each year.

For the purpose of the experiment a fixed number of fry, based upon the shore feeding area, has been set for annual planting in the lake. The number of trout caught by the anglers can be obtained

with a reasonable degree of accuracy as well as ages of a majority of the specimens. Finally quantitative determinations of the natural food supply are being made at set intervals during each year.

It would appear that all the data necessary for the determination of the relation between productivity and fishing drain are here available and it should be possible after a period of years of observation and experiment to develop a definite policy by which the stock of Kamloops trout in Paul lake may be maintained at a constant and high level.

CONCLUSION

This paper is an attempt to present a comprehensive picture of the scope and problems of fish culture and to indicate the aim of the research program as being developed in this field in Canada.

In conclusion it may be said that fish culture has entered a new era. Its future progress will be based upon the results of sound research and the application of scientific principles in every phase. To the researcher it offers one of the most enticing and promising fields in fishery biology, and to the administrator it offers one of the most challenging fields for the development of a system of scientific management of a great natural resource.

THE ABILITY OF SEVERAL SPECIES OF FISH TO SURVIVE ON PROLONGED EXPOSURE TO ABNORMALLY HIGH CONCENTRATIONS OF DISSOLVED OXYGEN

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Last year at the meeting of this Society one of us, Wiebe ('32) reported on some experiments that were performed to test the ability of several species of fish to live under an atmosphere of pure oxygen resulting in some instances in abnormally high concentrations of dissolved oxygen. During the discussions of that paper the point was made by some one that fish could survive such treatment during transportation but that they died within a few days after they had been planted. Because of the impression prevailing quite generally that the fish did not survive an exposure to abnormally high concentrations indefinitely, it was decided to perform some additional experiments. We, therefore, present here the results of some experiments performed to show that some species of fish at least can stand a prolonged exposure to abnormally high concentrations of dissolved oxygen and show further that these fish survive the experiment indefinitely.

Warm-water Fish

Experiment 1—For this experiment two tanks, C and D, were used. Tank C was stocked with four smallmouth bass (9.0-12.8 cm), five largemouth bass (9.7-11.5 cm), three goldfish (7.0-9.0 cm) and one bluegill (13.8 cm). Tank D was stocked with ten largemouth bass (6.5-7.8 cm), one black crappie (11.0 cm), six bluegill (6.4-11.1 cm), three goldfish (6.0-7.0 cm), and one orange-spotted sunfish (9.1 cm). These fish were placed in the aquaria on January 25th when the oxygen content was normal, namely, 8.6 and 8.7 p.p.m.

After the fish had been placed in the aquaria the O_2 content was raised by aerating the water with compressed oxygen. The experiment was continued for twenty days. After that the O_2 was allowed to go down until it reached a normal value.

During these twenty days two of the largemouth bass in tank D died. The rest of the fish all survived and are as healthy and lively today (September 8th) as they were before the experiment (January 24th).

Table 1 gives the values for dissolved oxygen for experiment 1. The table shows that in tank C after the first day the O_2 was never less than 18.4 p.p.m. and the percentage of saturation never lower than 183%. The maximum figures for dissolved oxygen and per cent saturation in tank C are 32.2 (p.p.m.) and 324 (%). For practically

the entire period of the experiment the per cent saturation exceeded 200% and for nine successive days it either equalled or exceeded 300%. In tank C the minimum for dissolved oxygen after the first day was 20.0 p.p.m. and the minimum per cent saturation 199%. The maximum figures for dissolved oxygen and per cent saturation in tank D are 34.2 (p.p.m.) and and 344 (%) respectively. Here as in tank C the per cent saturation exceeded 200% for the greater part of the experiment, and for fourteen consecutive days it ranged from 299% to 344%.

Some of the data for dissolved oxygen and per cent saturation for experiment 1 are shown graphically in Figure 1; with the exception of January 25th and February 13th only the pm value of Table 1 are plotted in Figure 1.

The pH in C varied from 7.3-7.85 and in D from 7.4-8.1. The temperature in both tanks ranged from 14.5-17.0° C.

TABLE 1. SHOWS O_2 IN PARTS PER MILLION AND THE PER CENT SATURATION FOR EXPERIMENT NUMBER 1.

		Tank C		Tank D	
Date	Time	O_2 p.p.m.	% saturation	O_2 p.p.m.	% saturation
Jan. 25	11:00 AM	8.6	80.4	8.7	81
Jan. 25	4:00 PM	10.1	95.3	10.7	101
Jan. 26	8:30 AM	19.3	184	20.1	192
Jan. 26	4:00 PM	21.2	209	21.8	208
Jan. 27	9:00 AM	23.2	229	24.1	237
Jan. 27	4:00 PM	23.9	228	24.3	242
Jan. 28	9:00 AM	24.4	232	25.2	251
Jan. 28	4:00 PM	24.4	245	25.5	256
Jan. 29	9:00 AM	24.0	239	25.5	254
Jan. 29	4:00 PM	24.4	243	25.5	254
Jan. 30	8:00 AM	24.2	238	25.7	253
Jan. 30	4:00 PM	24.0	236	25.8	254
Jan. 31	5:00 PM	24.1	237	25.8	246
Feb. 1	8:30 AM	24.3	234	26.5	256
Feb. 1	4:00 PM	24.4	233	26.5	253
Feb. 2	8:30 AM	22.1	228	23.7	253
Feb. 2	4:00 PM	22.5	222	25.3	249
Feb. 3	8:30 AM	21.7	214	24.5	241
Feb. 3	4:00 PM	21.4	211	24.2	238
Feb. 4	9:00 AM	21.1	210	23.6	235
Feb. 4	4:00 PM	18.4	183	20.0	199
Feb. 5	9:00 AM	30.0	302	32.5	323
Feb. 5	4:00 PM	30.4	306	33.8	341
Feb. 6	9:00 AM	32.2	324	34.2	344
Feb. 6	5:00 PM	32.0	322	33.5	337
Feb. 7	6:00 PM	31.4	316	32.6	328
Feb. 8	9:00 AM	32.0	322	33.2	330
Feb. 8	4:00 PM	31.9	321	32.9	331
Feb. 9	9:00 AM	31.3	315	32.7	329
Feb. 9	4:00 PM	29.8	300	31.2	314
Feb. 10	9:00 AM	28.0	294	30.4	309
Feb. 10	4:00 PM	28.2	289	30.3	308
Feb. 11	9:00 AM	27.0	278	29.5	302
Feb. 11	4:00 PM	26.6	273	29.1	299
Feb. 12	9:00 AM	26.4	271	29.2	300
Feb. 12	4:00 PM	26.4	271	29.0	298
Feb. 13	9:00 AM	26.3	266	29.0	291

Experiment 2—In this experiment four yearling largemouth bass measuring between 22-25 cm were transferred from O_2 6.2 p.p.m. to an O_2 content of 18.59 p.p.m. The water was then aerated with compressed oxygen for fourteen days. During this period, as is shown

by Table 2, the concentration of dissolved oxygen ranged from 13.8 p.p.m. to 30.6 p.p.m. and the per cent saturation from 160% to 356%. For nine days the per cent saturation exceeded 250%. These fish all survived the experiment and are alive today, fifty-three days after the conclusion of the experiment.

One seven-year-old largemouth was transferred from water having an O_2 content of 6.2 p.p.m. to water having an O_2 content of 25.9 p.p.m. It was kept in this water of high O_2 content for six days. During this time the lowest O_2 value was 22.9 p.p.m. and the highest 28.3 p.p.m. The per cent saturation ranged from 265-329%. This fish is still alive after fifty-three days. This experiment was performed at a temperature of 23° C.

TABLE 2. SHOWS VALUES FOR DISSOLVED OXYGEN IN PARTS PER MILLION AND PER CENT SATURATION FOR EXPERIMENT 2.

Date	O_2 p.p.m.	% saturation	Date	O_2 p.p.m.	% saturation
July 15 8:00 AM	18.59	216	July 24	13.8	160
July 16 8:00 AM	21.90	255	July 25	14.9	172
July 17 8:00 AM	22.08	257	July 26	25.3	294
July 18 8:00 AM	17.1	199	July 27	24.5	286
July 19 8:00 AM	22.1	257	July 28	22.1	257
July 20 8:00 AM	22.7	264	July 29	30.6	356
July 21 8:00 AM	19.8	230			
July 22 8:00 AM	23.2	269			
July 23 8:00 AM	17.2	201			

Experiment 3—A similar experiment as outlined above was performed, using blunt-nosed minnows (4.8 cm-7.8 cm), bluegill (4.2-4.5 cm), goldfish (4.5-7.0 cm), white crappie (2.0-3.0 cm), largemouth bass (6.2-7.0 cm and 10.8-11.8 cm), black crappie (14 cm), green sunfish (6.5-11.0 cm), and the same smallmouth bass that were used in Experiment Number 1. In this experiment the per cent saturation ranged between 166% to 325% for a period of fifty days. For the greater part of the period the per cent saturation was in excess of 200%. With the exception of one of the larger largemouth, one smallmouth and the small, white crappie all fish survived the experiment. The crappie began dying after they had been exposed to high oxygen for thirty-nine days. We had no food that they would take and hence they wasted away. The remaining fish were kept under observation for four months but no ill effects became evident.

Experiment 4—In still another experiment one 21.75 cm largemouth bass was placed in an air-tight container with a layer of pure oxygen over the water. The pressure was raised to 23 pounds. After sixty-nine hours when the pressure still amounted to 18.5 pounds the fish was taken out. This fish showed no ill effects from the treatment. It was kept under observation for six months without showing any after effects. Another bass of the same size that had been kept under a pressure of from 12-13 pounds for the same period of time survived equally well.

From the above results it would appear that these warm-water fish could stand a very wide range in dissolved oxygen after a certain minimum value has been attained.

Experiment 5—Gutsell (1929) reported that trout could be acclimated to low oxygen. We have been able to get some evidence of this type for the largemouth bass. Fish that had been acclimated to 6.0 p.p.m. when placed in a definite volume of water containing 2 p.p.m. of O_2 in a stoppered flask had all died when the O_2 reached 0.8 p.p.m. and the average survival time was 8.5 hours. Fish that had been acclimated to 2.0 p.p.m. of O_2 had an average survival time of 9.5 hours under similar conditions. The final O_2 here was 0.7 p.p.m. The difference in the lethal concentration of O_2 is not significant but the one hour's difference in the survival time may be.

We have also obtained some evidence to show that when fish have been acclimated to low oxygen they consume oxygen at a lower rate than do fish that have not been so acclimated. Largemouth bass that had been acclimated to 6 p.p.m. survived for fifteen hours when placed in a definite quantity of water in a sealed flask containing 5.9 p.p.m. O_2. The final concentration of O_2 was 0.6 p.p.m. Fish that had been acclimated to 2.0 p.p.m. of O_2 survived similar conditions for nineteen hours. The final O_2 in this case was 0.5 p.p.m. The difference of four hours in the length of time that they survived may be significant.

Trout

In this section are reported several experiments similar to those outlined in the preceding part. Only in this case trout were used instead of warm-water fish.

Experiment 6—In this experiment two tanks, C and D, were used. Tank C was stocked with six rainbow trout (12.5-15.0 cm) and tank D with twenty-five rainbow trout (4.0-5.0 cm) and twenty-five brook trout (4.0-5.0 cm). After the fish had been placed in the aquaria the water was aerated with compressed oxygen. These fish were exposed to high oxygen for twenty days. After that the oxygen tank was disconnected and compressed air substituted. During these twenty days the concentration of dissolved oxygen in tank C ranged from 21.0-33.0 p.p.m. and the per cent saturation from 209% to 328%. For almost the entire period the per cent saturation exceeded 250%. In tank D the concentration of O_2 ranged from 25.5-31.4 p.p.m. and the per cent saturation from 251% to 312%. In this tank the per cent saturation was never below 250 during the twenty days of the experiment. The fish all survived the experiment and four weeks after the experiment was completed only six of the small trout had died. The medium sized trout all lived indefinitely.

The temperature ranged from 14.5-15.8°C. during this experiment and the pH from 7.8-8.15. The data for dissolved oxygen and per

cent saturation are shown in Table 3. They are also shown graphically in Figure 2.

TABLE 3. SHOWS O_2 IN PARTS PER MILLION, AND PER CENT SATURATION FOR EXPERIMENT NUMBER 5

	TANK C		TANK D	
Date	O_2 p.p.m.	O_2% saturation	O_2 p.p.m.	% saturation
April 12	23.9	238	26.7	266
April 13	21.0	209	25.5	251
April 14	27.1	270	30.2	300
April 15	27.5	273	29.7	296
April 16	26.4	263	27.0	269
April 18	29.1	290	31.3	311
April 19	27.9	278	29.5	294
April 20	28.5	284	30.5	303
April 21	28.0	278	26.8	267
April 22	26.1	260	25.5	256
April 23	30.3	302	30.2	304
April 25	32.2	320	31.1	309
April 27	33.0	328	31.4	312
April 28	31.9	318	30.2	300
April 29	30.7	307	29.0	290
April 30	27.7	276	26.1	260
May 2	31.1	303	26.7	260

Experiment 7—In this experiment five rainbow trout (12.5-15 cm) and sixteen brook trout (4 cm-5 cm) were transferred from water having an O_2 content of 7.4 and 8.4 p.p.m., respectively, to water having an O_2 content of 29.9 p.p.m. They were kept in the water of high oxygen content for two days when they were transferred from 29.5 p.p.m. to 7.2 p.p.m. The small brook trout all survived for three weeks after which they were liberated. Two of the rainbow trout died: one while in the high oxygen and one shortly after they had been transferred to normal oxygen. The remaining three survived indefinitely.

Experiment 8—In this experiment five rainbow trout (12.5-15 cm) were kept under an atmosphere of pure oxygen under an initial pressure of 20 lbs. which during the duration of the experiment (45 hours) decreased to 10 lbs. The dissolved oxygen reached a concentration of 58.1 p.p.m. twenty hours after the experiment was begun. When the experiment was terminated the O_2 amounted to 51.8 p.p.m. From this concentration the trout were transferred to water having 8.4 p.p.m. For a minute or so the fish were dazed but they soon began to move around although their breathing was labored. The next day one of these fish was dead. The other four survived indefinitely. The temperature in this experiment ranged from 13.5-14°C.

Experiment 9—In this experiment twenty-five rainbow trout (4.0-5 cm) were transferred from water that had an O_2 content of 8.2 p.p.m. to water in a pressure can that had an O_2 content of 16.5 p.p.m. The can was then closed and part of the water displaced by O_2 from a tank, thus creating a layer of oxygen over the water. The pressure was raised to 13.23 lbs. This was at 10:15 A. M., April 18. At 8:30 A. M., April 19, the pressure was down to 7.85 lbs. and the

O_2 amounted to 58.1 p.p.m. The pressure was again raised to 13.23 lbs. At 4:00 P. M. of the same day the O_2 was up to 65.0 p.p.m. The next morning at 8:30 the O_2 was down to 63.3 p.p.m. and the pressure to 6.2 lbs. At 12:30 P. M. the pressure was down to 3.81 lbs. and the O_2 to 57.5 p.p.m. The fish were taken out at this time and put into water having an O_2 content of 9.7 p.p.m. All the trout had survived the experiment and did not mind the transfer from 57.5 p.p.m. to 9.7 p.p.m. of dissolved oxygen. Two weeks after this experiment was completed not a single one of these fish had died. The temperature in this experiment ranged from 12.5-13.0°C.

These results would tend to show that the rainbow and the brook trout can tolerate a very wide range in the concentration of dissolved oxygen.

CONCLUSION

The data presented here seem to show:

(1) That certain sizes of: crappie, largemouth bass, smallmouth bass (Northern), green sunfish, bluegill, goldfish, golden shiners, blunt-nosed minnows, orange-spotted sunfish, rainbow trout and brook trout tolerate a prolonged exposure to abnormally high concentrations of dissolved oxygen.

(2) That the above named species of fish survive this exposure indefinitely.

No cases of gas-bubbles or of pop-eye were observed in spite of the fact that we were on the look-out for these symptoms.

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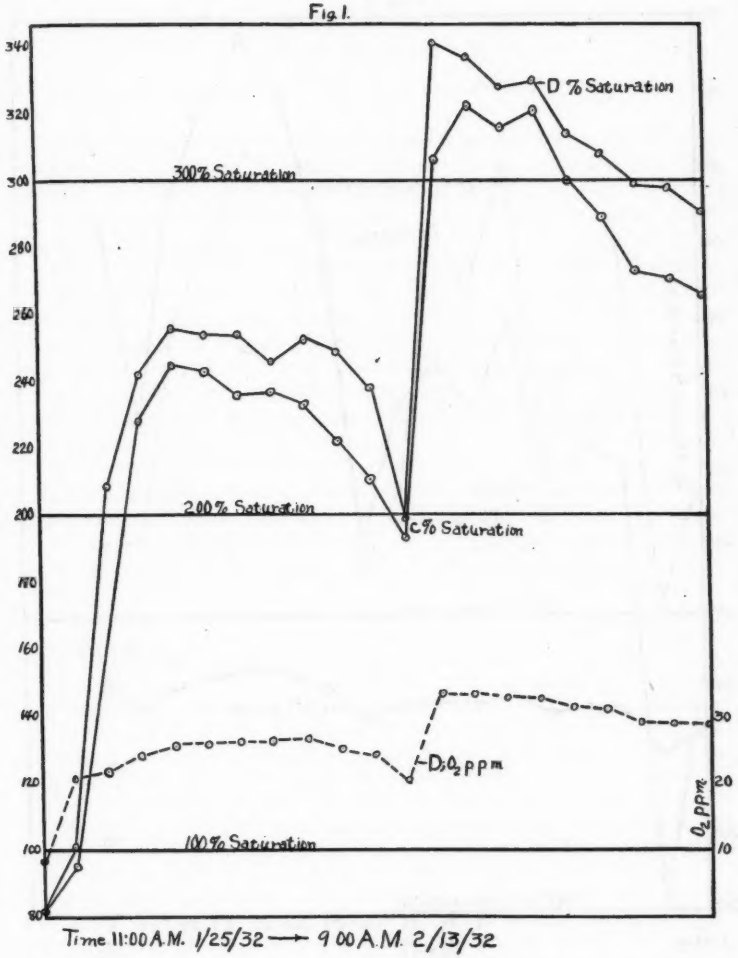

Fig. 1. Shows per cent of saturation with O_2 in both tanks, in experiment number 1 and also parts per million for tank B.

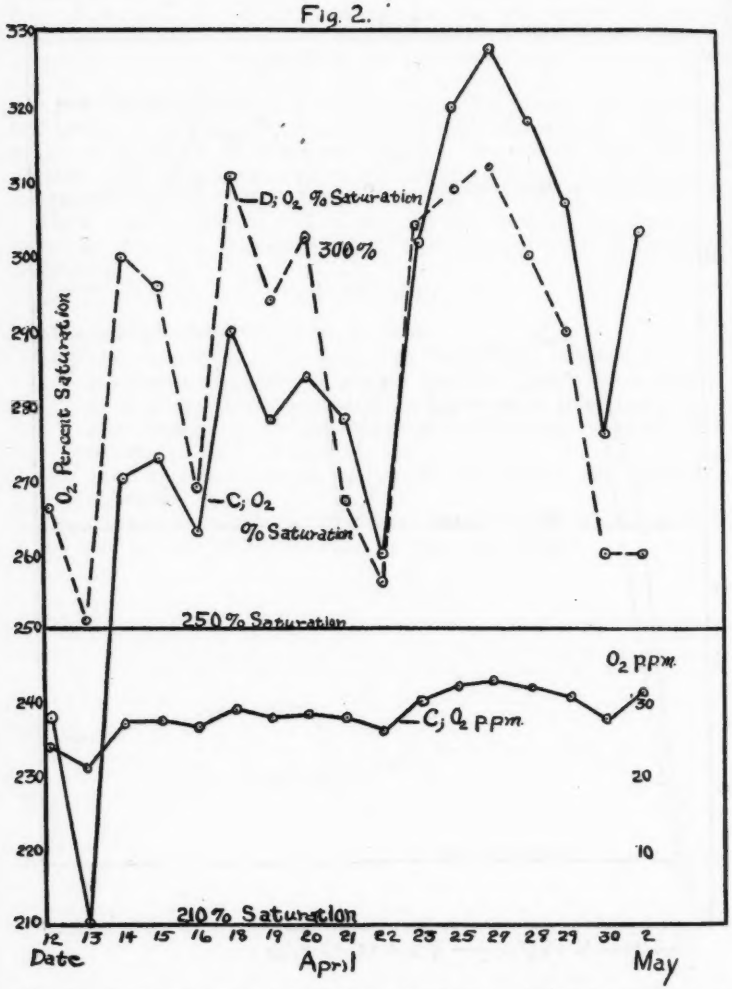

Fig. 2. Shows per cent of saturation with O_2 in both tanks in experiment number 6 and also parts per million for tank C.

ARE NEWLY IMPOUNDED WATERS IN OHIO SUITABLE FOR FISH LIFE?

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During the last three weeks of August and the first week of September, 1932, Mr. Lee S. Roach, biology teacher, Urichsville High School; Mr. M. B. Trautman, Assistant, Division of Conservation, and I, made a preliminary, physical, chemical and biological study of twelve bodies of impounded waters in Ohio. The object was to compare the productivity of these reservoirs from the standpoint of fish production. The reservoirs are located in western, central and northeastern Ohio; range in size from eighty acres to 15,500 acres; vary in depth from six feet to sixty feet, and are from eight and one-half months to 100 years old. Several sampling stations, at representative places, were established in each body of water and although a number of physical and chemical tests, together with quantitative food studies, were made, they will not be mentioned here, except in connection with certain points to be stressed.

While this paper is only preliminary in nature and we know very little about the basic problems of fish propagation, after a stream or canal is impounded by a dam or embankment, nevertheless it seems advisable at this time to offer a few suggestions that may assist in working out a fish propagation policy for such waters.

The first question is: how long, after a stream or canal is transformed into a reservoir, does it take for available fish food to develop in sufficient quantities to support fish life? By making actual counts at various water depths of the small crustaceans (copepods and waterfleas), which are the first food of our fishes after the food sac is absorbed, we found, generally, a good crop of these and also of the microscopic plants (algae), which are in turn the food of the small crustaceans. This was true for waters recently impounded (8½ to 14 months) as well as those impounded for as long as ninety to 100 years. The counts of bottom organisms, especially the midge larvae, which are the second food stage of a number of our game fishes, are in general as high in the newly impounded waters as in some of the older waters. On the other hand, forage fishes, except the gizzard shad in certain reservoirs, were lacking, and this was especially true in the newly impounded waters, although the food of the shad was there in abundance. Upon the presence or absence of this fish seems to rest the burden of whether or not impounded waters in Ohio will be productive of several game fish, although the brook silverside (*Labidesthes sicculus*) and the golden shiner, are undoubtedly of importance.

Our second question is: how long after a stream is impounded, do its characteristic stream fishes tend to disappear and its lake species begin to come in? We have some evidence this may take place within eight and one-half months, because in 1929 we recorded thirty stream species from Meander creek, which is now flooded, and recently we took only twelve species and these were principally lake forms. On the other hand, we have recorded fifty kinds of fishes from waters impounded from ninety to 100 years. This seems to show that, as a reservoir grows older additional lake species may be added from time to time and stream fishes disappear. The white crappie, bluegill, pumpkinseed sunfish, largemouth bass, bullhead catfishes and channel catfish, are the food and game species that may become dominant in impounded waters. The white crappie, presumably, becomes abundant first and may continue to dominate if there is a large expanse of suitable open water, although if rooted aquatic vegetation develops the bluegill, pumpkinseed sunfish and largemouth bass, will usually do well.

Since forage fish are generally lacking and other forms of potential fish food, as a rule, available in sufficient quantities, what is the solution to the problem? In Ohio we believe it is the gizzard shad (*Dorosoma cepedianum*) ond our reasons for thinking this are as follows: food studies of fingerling and adult gizzard shad by Forbes in Illinois, 1888, and by Tiffany in Ohio, 1920-21, show they feed primarily upon microscopic plant life suspended in the water and since this food, together with small crustaceans, soon becomes abundant in newly impounded waters and is not utilized to any extent by the other 162 kinds of Ohio fishes, except possibly the suckers, it represents a direct connecting link between microscopic plant life and game fishes. This was pointed out by Forbes and by Tiffany, but to my knowledge has not been utilized to any extent by conservation departments. The gizzard shad competes with very few fish for spawning grounds because it does not make a nest but deposits its eggs in the open water, especially along shore, although this may be detrimental to eggs deposited along shore if the water level fluctuates during May and June to such an extent that the eggs are exposed and die. The gizzard shad being primarily an open water species, offers very little competition with other fishes for shelter. It cannot ordinarily be caught on hook and line; therefore, will not be depleted by this method. It does not have spines, is soft bodied, usually swims in large schools at the surface and makes an attractive bait because of its silvery color. At the end of the first summer it averages about four inches in total length. During the summer months we have found largemouth bass, white bass, white crappie, black crappie, bullhead catfishes and channel catfish, feeding largely upon it.

There are of course objections to using impounded waters for fish propagation and undoubtedly the most serious is correlated with the

water level, because if this is not maintained, especially during the spring spawning season, practically the entire hatch of forage fish and also game fish may be lost. Fortunately, this appears to be the time the water level fluctuates the least. Trying to grow rooted aquatic vegetation with a fluctuating water level, presents another problem. If the water is too deep there may be a bottom layer with little or no oxygen and even though this sheet of water may contain an abundance of potential fish food, fish cannot live continuously in it because of the low oxygen content during the hot summer, although they may enter it temporarily for food. During the time of this investigation less than one and one-half parts per million of oxygen was found in depths varying from thirteen to thirty-three feet in the different reservoirs. Adequate spawning grounds may also be lacking, together with suitable shade and shelter, for game species.

The shad offers some difficulties in fish propagation because there may be a certain natural mortality in the spring and fall. It is hard to transport as it dies rather easily, when handled.

Discussion

MR. CULLER: I would like to ask Mr. Wickliff if he transported these fish in any numbers?

MR. WICKLIFF: Yes, we carried these gizzard shad into Guilford lake and Lake Alma, and to my knowledge there has not been any mortality. The gizzard shad is a delicate fish to handle, therefore you must take precautions in transporting it, but undoubtedly if you transport it in the early spring or early fall you should meet with a reasonable degree of success.

SOME OBSERVATIONS ON THE INTERRELATIONSHIPS OF SUNLIGHT, AQUATIC PLANT LIFE AND FISHES

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and

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In the course of certain pollution studies in Minnesota, a number of interesting observations have been made on the effect of sunlight on the oxygen content of waters rich in aquatic plant growth. The amount of dissolved oxygen which is contained in water is of primary importance to the fishes therein, directly, as it is concerned in their respiration, and indirectly, in its effect upon smaller food organisms. The plants themselves, although producing oxygen at certain periods, are dependent upon dissolved oxygen for their respiration. It is the purpose of this paper to present a few first-hand observations on some of the relationships existing between sunlight, aquatic plant life and fishes.

The dissolved oxygen determination is made for the purpose of ascertaining the amount of free oxygen which is dissolved in the water. This does not involve oxygen which is combined with hydrogen to form the water itself, or oxygen which is combined with other substances dissolved in the water, but is that which is free and available for the respiratory functions of animals and plants, or for chemical combination with other elements and compounds.

The amount of oxygen which may be dissolved in water at normal atmospheric pressure varies with the temperature from 7.63 parts per million at 86 degrees Fahrenheit, to 14.62 parts per million at 32 degrees Fahrenheit. It is to be noted that water has its greatest affinity for oxygen at low temperatures. Sometimes, the condition of supersaturation is encountered and the dissolved oxygen may reach a peak of 25 parts per million or more, in spite of the fact that the temperature is high.

This phenomenon of supersaturation has its origin in certain physiological life processes carried on by chlorophyll-bearing (green) plants. The specific substance involved is a complex chemical combination of elements called chlorophyll, which, under favorable con-

MR. T. SURBER: It was my suggestion that this paper be prepared by Mr. Olson for submission to this meeting of the American Fisheries Society. A good deal of it is not new matter to most of the members, but my idea was to give the results so that the presentation of papers on the same subject in the next few years to come might be stimulated. In informing the rank and file of the people of Minnesota with regard to certain phenomena I have found it pretty difficult to explain why such things occur and what their causes are.

ditions, has the power of manufacturing food. In the presence of sunlight, this greenish substances can produce starch when supplied with carbon dioxide and water. In the process of starch manufacture, oxygen is formed as a waste product. In aquatic plants, the only means of eliminating this waste product is through the surrounding medium, and, as a result, the water often becomes loaded with oxygen to and beyond the point of saturation. In a lake or stream, this condition may often be observed at the end of a bright, sunny day, during which the photosynthetic (food manufacturing) activities have been going on at a maximum rate.

At night, there is no sunlight to provide the necessary energy for photosynthesis, and, in place of producing oxygen, the plants use a considerable quantity of it for their respiration. The result is a demand by both plants and animals upon the available oxygen supply during the hours of darkness. In cases where a large quantity of decomposing organic matter, such as sewage, is added to an aquatic environment rich in plant life, the nightly reduction in oxygen may become serious. This would be especially true after a series of cloudy days, for, during cloudy weather, oxygen production is much curtailed and the water would not have a sufficient reserve supply to last the night.

In the fall of the year, many aquatic plants die off and their remains settle to the bottom, where they gradually decompose during the winter. Under ordinary conditions, where plant growth is not excessive, the decay of the organic matter from this source is not a serious drain upon the oxygen supply. However, where plant growth has been excessively stimulated by fertilization, this drain upon the oxygen resources may be considerable. A superabundance of organic matter means an increased demand upon oxygen in the natural process of decomposition.

The fertilization mentioned may be caused by sewage and industrial waste pollution. Fine particles of organic matter contained in the waste settle to the bottom where they are attacked by bacteria and broken up into soluble substances which are used as food for aquatic plants. Ordinarily, the only source of nitrogen and sulphur to which aquatic plants have access is that supplied by the decomposition of animals and plants already in the environment. Vegetation must limit itself to the growth permitted by this supply. The sulphur found in the complex structure of dead cells passes through a cycle of putrefaction, producing hydrogen sulphide. Oxidation produces sulphates, which are then utilized by the plants in the formation of protein. The nitrogen also goes through a cycle in which the decay of organisms and waste material, plant and animal, gives rise to ammonia compounds. These ammonia compounds are used directly by some organisms. Usually, however, the nitrogen of the ammonia compounds is carried to the nitrite, and finally to the nitrate stage. In this latter form, it is one of the chief foods of plants

in building up protein. Since the sewage pollution mentioned above adds much organic matter to the environment, it also brings about an increase in available nitrogen and sulphur. The environment is thus thrown out of its natural balance and the result is a tremendous increase in plant growth, which may or may not have a deleterious effect upon the environment.

In our northern lakes, the winter months are characterized by the formation of an ice covering, often darkened by a blanket of snow, which effectively seals the body of water from surface aeration and reduces photosynthesis to a minimum. If, in such an event, there is a steady influx of sewage and other waste containing a great amount of suspended and dissolved organic matter, there is a drain upon the oxygen resources from three directions, (1) the oxygen needed by living aquatic animals and plants for their respiration, (2) the oxygen necessary in the oxidation of decaying animals and plants already in the area (possibly increased by the fertilizing effect of the long continued sewage pollution), and (3) the oxygen demand exerted directly by the sewage or other wastes contributed from a source outside the area.

When there is sewage pollution in a shallow body of water having little or no circulation, the oxygen is frequently entirely used up and fish within the area are exterminated. Anaerobic decomposition usually follows and foul odors are produced. In certain cases, this condition may be limited to portions of a lake rather than the body of water as a whole.

Although the supersaturation of water with dissolved oxygen had been observed earlier, the first attempt to determine the extent and importance of this phenomenon was made during the summer of 1929. During a routine investigation of Pokegama lake on July 25 of that year, it was noted that the dissolved oxygen content of the water was extremely high. There was then an extensive algal bloom in the lake consisting chiefly of the short, slender, blade-like colonies of Aphanizomenon. These colonies, superficially resembling short lawn cuttings, were floating about freely in the upper stratum of the open water, and were concentrated along the beaches to form a thick paint-like mixture having a distinctly obnoxious "pig pen" odor. Even in the open water the colonies were so abundant that an object lowered into the lake was visible for a few inches only.

Tests were made for dissolved oxygen a short time before sunset on the 25th. In all samples taken three feet or less from the surface, the water was supersaturated with oxygen. In one sample having a temperature of 80 degrees Fahrenheit, the dissolved oxygen content was 17.7 parts per million, when it should have been 8.12 parts per million. In another sample taken where algae were not quite as abundant, there were 9.65 parts per million of dissolved oxygen, when the water would have been saturated if it had contained 7.63 parts per million. At a depth of eighteen feet, conditions were quite

different, and the effect of oxygen production by photosynthesis was not in evidence. Here the water contained only 3.3 parts per million of oxygen, or 38% of the amount it could have had if saturated.

In order to determine the extent to which the respiratory activities of living organisms, and the oxidation of organic substances reduced the dissolved oxygen during the night, a number of samples were taken before sunrise on the 26th. Samples were collected about three o'clock in the morning at points corresponding to those used the preceding evening. A sample taken where algae were most abundant showed a reduction of dissolved oxygen from 17.7 parts per million to 4.2 parts per million, or from 218% saturation to 48% saturation. Samples taken in deeper water had neither lost nor gained dissolved oxygen, but still contained 3.3 parts per million at a depth of eighteen feet.

The fluctuation, it will be noted, took place in the upper stratum of the water where algae were abundant and sunlight was strongest. Eighteen feet below the upper surface, where much of the sun's energy had been intercepted, and where fewer organisms were then congregated, the fluctuation did not take place. Dissolved oxygen was as low after a long sunny day as it was after a dark moonless night.

Since 1929, the phenomenon of supersaturation has been observed again and again, where algal blooms were in evidence or submerged aquatic vegetation was very abundant. In several cases, supersaturated conditions have been noted in streams. Since undue agitation does not permit saturation, these streams have naturally been slow in movement and without rapids and falls. The presence of an extensive algal bloom has always been observed in these streams when high oxygen concentrations occurred.

In 1928 and 1929, great quantities of the blue-green alga, *Alphanizomenon*, were observed in the Cannon river. During the same period, this alga also characterized a series of lakes which are interconnected by this river. Tests for dissolved oxygen showed that the river water was supersaturated whenever there was enough sunlight to encourage photosynthesis. The highest oxygen content of the water during the period was 112% saturation. In 1931, the Minnesota river near Redwood falls contained an algal bloom which increased the oxygen from its ordinary saturation of 8.5 parts per million to 15.5 parts per million, or approximately 183% saturation. Similar occurrences were also observed in the upper reaches of the Straight river in 1928-1929, and in the south fork of the Crow river in 1930. In the latter case, a bloom of *Anabaena spiroides* and *Microcystis aeruginosa* appeared by the middle of August, imparting the usual blue-green color to the water and forming masses of scum at the surface where obstructions blocked the stream. Although the temperature was 80.6 degrees Fahrenheit, the dissolved oxygen content of the

water rose to 24.1 parts per million in this instance. This represents a saturation of 298.6%.

In addition to the free-floating algae, there are other non-plankton forms and submerged forms of higher plants which play an important part in producing a condition of supersaturation. A study of the hourly changes in dissolved oxygen in a weedy part of Clearwater lake at Waconia, Minnesota, demonstrates the effectiveness of these types of vegetation in oxygen production. An investigation of this bay was undertaken on July 22 of this year for the purpose of determining the effect of sewage pollution in summer on the oxygen content of the water in an area thickly overgrown with the higher types of submerged aquatic vegetation and non-plankton algae. The bay in question is situated in the southwest portion of the lake where it receives a quantity of partially treated domestic sewage from the city of Waconia, and the untreated milk wastes from a large creamery. From past observations, it was known that high oxygen concentrations can be expected during the day in a heavily vegetated area such as this, but there was no way of knowing the reduction which would occur during the night as a result of the presence of organic wastes which constantly demand oxygen for stabilization. For this reason, more accurate information concerning the nocturnal reduction was desired, and hourly samples were taken for analysis. The results obtained show the effect of pollution on the dissolved oxygen in water which would, under ordinary circumstances, be supersaturated, and since no definite bloom of plankton occurred at this time, the results also indicate the importance of other types of aquatic plants in the production of oxygen.

Samples were collected from four points in the bay, designated as stations A, B, C, and D. Station A was located near the creamery waste outlet where the influence of this waste would be most noticeable. A thick bed of submerged vegetation, consisting chiefly of Ceratophyllum, Myriophyllum, and two species of Potamogeton, and situated about 500 feet west of the creamery outlet, was selected as Station B. This station was halfway between the two sewer outlets mentioned previously. Stations C and D were located farther from the sources of pollution. Station C represented an area which was free from the larger types of vegetation but overgrown by a non-plankton alga, *Hydrodictyon,* more commonly known as "water net." A small quantity of this water net grew at Station D, but the area was near the edge of the bay and thus represented a transition from dense vegetation to open water.

Samples were collected hourly from 10 A. M., July 22, until 9 A. M., July 23. A steady increase in oxygen was observed as the water warmed up and the sunlight became more effective. By five o'clock in the afternoon, the water was supersaturated with oxygen at all stations, and this condition prevailed until midnight. At that time, a general reduction of oxygen began, so that by 1 A. M., the dissolved

oxygen was below saturation at all stations, with the exception of Station D situated near open water. With a few minor irregularities, this decrease continued until sunrise at 4:48 A. M.

The fluctuation of oxygen was very marked during the twenty-four-hour period. The greatest change from 300% saturation to 61% saturation occurred where Hydrodictyon formed the chief vegetation. An almost identical fluctuation characterized the area where the larger forms of aquatic vegetation were predominant, although the oxygen production during the day was less pronounced. The presence of pollution may have been responsible for the irregularities and for the low oxygen concentration (2.2 parts per million) observed at this station.

At Station D near the open water, there was a distinct fluctuation following the general trend observed at the other points, but the fluctuation was much more moderate. At this station the dissolved oxygen content dropped below the saturation point only once during the twenty-four-hour period, while at other stations the oxygen dropped below 100% at midnight and remained low for at least eight hours.

In the neighborhood of the sewer outlet, the dissolved oxygen remained below saturation practically all day, but finally increased at 5 P. M., reaching its peak at 9 P. M. This very peculiar occurrence can be explained by the fact that there was a brisk on-shore breeze during the period that these high oxygen conditions were prevalent. It seems that the wind was responsible for the increased oxygen, for the oxygen immediately dropped below the point of saturation at 1 P. M. when the breeze died down. The decrease then continued until 9 A. M. the following morning, when the dissolved oxygen reached its lowest point—1.6 parts per million.

This study demonstrated a definite fluctuation in the oxygen content of water during a twenty-four-hour period. There was in all cases a tendency for the oxygen to increase from sunrise until the late afternoon. This was followed by a decrease, continuing until the following sunrise. It was also noted that where plant life was most luxuriant, the oxygen was produced in larger quantities and the range of fluctuation was greatest.

From the results obtained, it is evident that non-plankton algae and the larger forms of submerged aquatic vegetation, as well as plankton blooms, are important in the production of high oxygen concentrations which bring about a condition of supersaturation. It is also evident that organic pollution may keep the dissolved oxygen below the saturation point even when under normal conditions sufficient vegetation and sunlight is available for the creation of a supersaturated condition.

In balanced aquaria, it has often been observed that excessive growths of plankton algae may so upset the balance that practically every fish and gill-breathing snail in the container is exterminated.

Recently, when a catastrophe of this kind occurred in an experimental aquarium containing a number of goldfish and snails, an analysis of the water showed that the organisms had died because of the lack of oxygen. The water was green with algae at the time, and oxygen should have been high if the proper amount of light had been available. Since, however, there had been insufficient light for a day or more, the delicate oxygen balance, necessary to keep fishes and snails alive, was disrupted and the oxygen was entirely depleted.

This is but a small-scale demonstration of the fish losses which may occur when an extremely heavy algal bloom occurs in a lake. An occurrence of this nature was observed in a small lake in Southern Minnesota in 1931. In June of that year, a very dense bloom of *Oscillatoria agardhii* appeared in Albert Lea lake, which is formed as an expansion of the Shellrock river. Because of its shallowness and the abundant growth of water weeds, the lake was an ideal place for plankton growth. Moreover, the water was well fertilized by the wastes from a packing house, and the effluent from a sewage treatment plant provided with primary treatment. The result was a production of algae which was so extensive that the water assumed a brilliant blue-green color, and objects lowered into the water were invisible at a depth of three inches.

On the first of July, when this bloom was at its height, thousands of dead minnows and many larger fishes were observed floating at the surface of the water along the lake shore and in the Shellrock river at the outlet of the lake where many fish had accumulated in a small eddy. Because of the fact that many species of fish were involved and practically all specimens showed a marked distention of the gills, lack of oxygen seemed to offer the best explanation of the loss. This was further substantiated when it was discovered that the algae-laden water contained only 2.8 parts per million of dissolved oxygen at noon on July 1, after a long morning of bright sunshine. Under ordinary circumstances, water containing an algal bloom would have been supersaturated with oxygen at that time.

For the purpose of ascertaining the role played by the algae themselves and other plankton organisms in the reduction of oxygen, a two-liter sample of the water was collected for observation at the laboratory. It was discovered that the algae and plankton organisms alone were able to reduce the dissolved oxygen content of the water to 0.7 parts per million after a period of eighteen hours without sunlight. After this experiment, a five-hour exposure to sunlight again increased the dissolved oxygen to 18.8 parts per million. If the oxygen requirements of fishes is added to that of the plankton organisms, it is evident that the oxygen may be entirely depleted during the night. The condition would be even more critical if a series of cloudy days without much wind disturbance occurred during the same period.

The matter of water movement by wind or current is also impor-

tant, aside from the increased surface aeration which it may bring about. When the water laden with a heavy algal bloom is perfectly quiet, the plants immediately below the surface layers are shaded and may not produce enough oxygen to fill all the needs; whereas, a slight agitation which circulates the algal filaments exposes a greater number of plants to the rays of the sun and carries active plants farther from the surface where the rising bubbles of oxygen may come in contact with water below the saturation point. The result is a uniform distribution of oxygen instead of a heavy concentration at the surface and a deficiency at a depth of a foot or more. The result is a uniform distribution of oxygen instead of a heavy concentration at the surface and a deficiency at a depth of a foot or more. The results of oxygen determinations in Albert Lea lake and the Shellrock river demonstrate this point. On July 1 the lake was perfectly quiet and there had been no wind disturbance for many hours. At that time, the dissolved oxygen was only 2.8 parts per million about one foot below the surface, a fact already mentioned. At the same time, a sample taken below the low dam which is situated at the outlet of the lake, showed that the water was supersaturated. The sample was taken in a large eddy where the current slowly but thoroughly circulated the algal filaments. The descent over the little dam may have increased the oxygen to the point of saturation, but this does not account for the supersaturated condition. The photosynthetic activities of the algae, circulated so that oxygenation would be most efficient, is, as far as these matters are known, the only means by which this supersaturation could have been accomplished.

Ordinarily, supersaturation of water with oxygen is a phenomenon encountered in summer weather only, when algae and larger aquatic plants are most abundant. During the fall and winter periods, an extensive algal bloom is an exceptional event. Larger aquatic plants in many instances die off in the fall with the approach of cold weather, and their remains sink to the bottom, where they are attacked by bacteria and other organisms, finally being oxidized to simpler substances. These forms are, therefore, of little value in the production of oxygen, and in reality, only serve as an extra drain on oxygen resources during the winter months. There are a few plants, however, that remain active through the winter, and these can produce oxygen in considerable quantities when light is available. When the ice is clear and free from snow, the oxygen production may continue until all needs are filled and a surplus is built up. This surplus cannot escape into the atmosphere because of the ice cover, and a condition of supersaturation may thus be produced.

On a sunny forenoon in the latter part of January, 1930, an example of this condition was observed in Pokegama lake near Pine City, Minnesota. There was little or no snow on the lake at that time, and at certain points in the lake, the green color of aquatic vegeta-

tion could be observed through the ice. When a hole was cut in one of the areas where vegetation was abundant, the water which was exposed immediately became effervescent with tiny bubbles, and a sample taken well below the surface showed that the water was supersaturated with oxygen. At zero degrees Centigrade, the water should contain 14.62 parts per million of dissolved oxygen, but in this case the oxygen content was 16.8 parts per million. This represents a saturation of 115% at a time when the ice was almost three feet in thickness.

In winter when heavy snow covers the ice and excludes the light, serious oxygen depletions may occur in shallow lakes crowded with fish life. Unless early spring thaws relieve the condition by permitting the influx of snow-water rich in oxygen, an enormous number of fishes may be exterminated during this season. In the early fall the ice usually has sufficient transparency to permit the light necessary for photosynthesis to pass through. Later in the season, however, a coating of slush or heavy snow may render the ice sheet almost opaque, and aquatic plants may use more oxygen than they produce. Since surface aeration is prevented by the tightly sealed ice cover, there is no way of replacing the dissolved oxygen consumed by living organisms, unless a large stream of water saturated with oxygen enters the lake.

In shallow lakes with no inlet or outlet, the latter source of supply is not available, and the competition for oxygen soon becomes very keen. In such lakes, a serious oxygen shortage is usually observed during February or the latter part of January. Although the low temperature reduces the rate of metabolism in fishes considerably in winter, and thus reduces their need for oxygen, it has not been observed that these fishes can withstand a complete oxygen depletion during that season. In fact, whenever an oxygen concentration of less than one part per million has been found, a great number of dead fish have also been seen or reported a few days later. Hibernating frogs, as well as fishes, are killed by the depletion of oxygen, and they are often observed where winter losses of fish have occurred.

In February, 1929, a number of observations were made on oxygen depletion in certain shallow lakes in the southern part of Minnesota, near Waterville. It was found that shallow lakes six to fifteen feet in depth were low in oxygen, while deeper lakes had an adequate supply. For instance, in Lake Tetonka, just east of Waterville, the water contained more than eleven parts per million of dissolved oxygen, while in other shallower lakes within a radius of five miles, the dissolved oxygen ranged from 0.0 to 0.8 part per million.

In McCabes lake, a small body of water densely vegetated and overcrowded with fish, the dissolved oxygen was 0.0 part per million. On the day following this analysis, 20,000 pounds of dead carp were removed by commercial fishermen who doubted the value of oxygen determinations.

In another shallow lake considerably larger than McCabes lake, commercial fishermen had discontinued operations because no live fish were recovered. In this lake, the dissolved oxygen varied from a trace to 0.15 part per million.

In Lake Sakatah, almost directly east of Lake Tetonka, the oxygen content of the water was less than one part per million. In the upper part of this lake, the dissolved oxygen was 0.65 part per million, while the water in a weedy bay near the east end contained 0.8 part per million. It was decided that the removal of rough fish would be advisable in this case. Only dead fish were taken in seine hauls made at the upper end of the lake, but two hauls made in the weedy bay where the dissolved oxygen had been a trifle higher netted the fishermen a total of 160,000 pounds of live carp. The commercial fishermen said that these fishes were pale in color, inactive, and, in many cases, very near death. However, after their transfer to cribs in Lake Tetonka, where dissolved oxygen was plentiful, they soon recovered their normal color and activity. In spite of the removal of the carp, a large number of dead fish appeared in the spring. It is evident from this that the attempt to relieve the overcrowded condition was too late to save the game fish.

Similar oxygen depletions occurred in other lakes the same year and have been observed in recent years, but the examples cited serve as a demonstration of a case, where shallow lakes are entirely depleted, while deeper lakes in the same locality have an abundance of dissolved oxygen.

It is evident that the interrelationship of sunlight and vegetation is very important to fish life. If a proper balance exists between the amount of sunlight, the concentration of plants, and the number of fishes in the aquatic environment, all is well. But if the light is cut down seriously, the plants cannot perform their photosynthetic work and may then enter into competition with the fish for oxygen. Likewise, a decrease or excessive increase in plant organisms may upset the balance. The fish themselves may possibly upset the balance by destroying the larger forms of aquatic vegetation. There is much of interest to be learned from further observations of these relationships.

VARIATION IN DISSOLVED OXYGEN DURING A 24-HOUR PERIOD

CLEARWATER LAKE

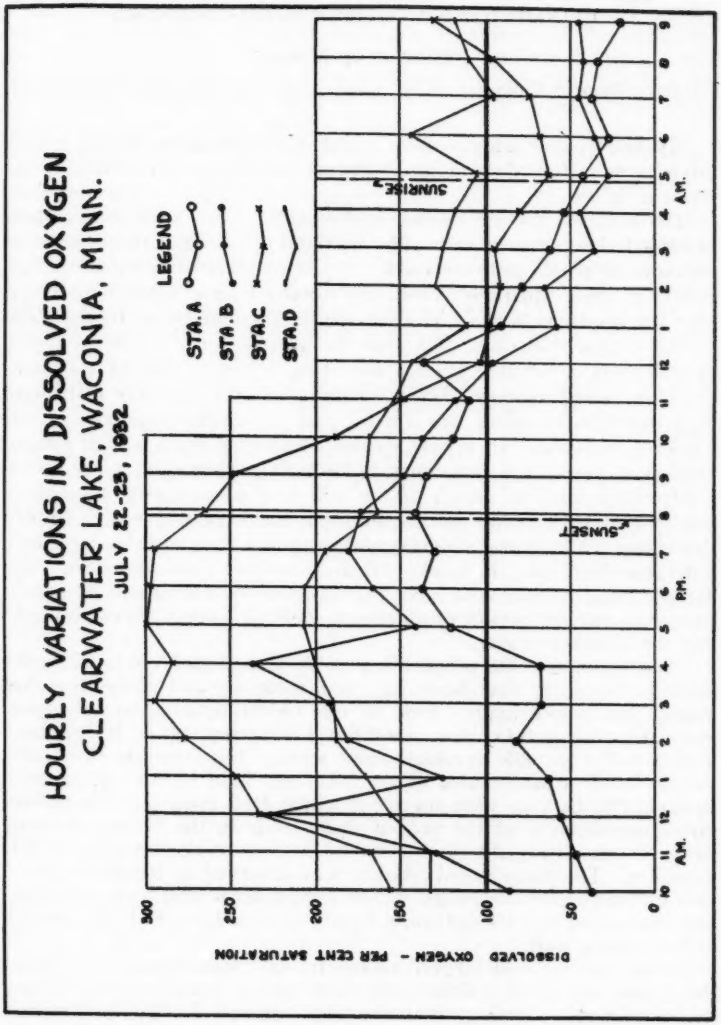
WACONIA, MINNESOTA

JULY 22-23, 1932

Time	STATION A			STATION B			STATION C			STATION D			STATION E		
	D.O.	°C. Temp.	% Sat.	D.O.	°C Temp.	% Sat.	D.O.	°C Temp.	% Sat.	D.O.	°C Temp.	% Sat.	D.O.	°C Temp.	% Sat.
10 A. M.	3.1	25	36.9	7.	26	85.1	12.8	26	155.7	11.3	24	132.5	10.7	24	125.4
11	3.9	26	47.4	10.5	26	127.7	13.8	26	167.9	11.3	24	132.5			
12 Noon	4.5	26	54.7	18.6	26	226.2	19.2	26	233.6	12.9	26	156.9			
1 P. M.	5.2	26	63.2	10.1	26	122.9	20.3	26	246.9	14.0	26	170.3			
2	6.6	27	81.7	14.6	27	180.9	21.9	28	276.5	15.1	27	187.1			
3	5.1	29	65.6	15.1	28	190.6	23.3	28	294.1	15.1	28	190.6			
4	5.1	29	65.6	18.7	28	236.1	22.5	28	284.1	15.6	29	200.8	12.9	27	159.8
5	9.3	29	119.7	11.1	28	140.1	23.8	28	300.8	16.3	28	205.8			
6	10.5	28	136.3	13.1	28	165.4	23.5	28	296.7	16.3	28	205.8			
7	10.3	28	130.	14.2	28	179.3	23.3	28	294.2	15.7	27	194.5			
8	11.6	26	141.1	14.2	26	172.7	21.7	26	264.	13.7	25	163.5			
9	11.1	26	135.	12.2	26	148.4	20.3	26	246.9	14.	26	170.3			
10	9.8	26	119.2	11.5	25	137.2	15.7	25	187.3	13.8	26	167.9	11.9	26	144.7
11	9.2	25	109.8	9.8	25	116.9	12.4	25	147.9	12.8	25	152.7			
12 M.	11.3	25	134.8	8.0	25	95.4	8.6	25	102.6	11.9	25	142.0			
1 A. M.	7.6	25	90.7	4.9	24	57.4	8.2	25	97.8	9.4	24	110.2			
2	6.5	25	77.5	5.5	24	64.5	7.8	24	91.4	10.7	25	127.7			
3	5.3	24	62.1	2.9	23	33.4	8.0	24	93.8	10.6	24	124.3			
4	4.6	24	53.9	3.7	24	43.4	6.9	23	79.5	10.0	24	117.2			
5	3.7	24	43.4	2.2	24	25.8	5.3	23	61.0	8.9	24	104.3			
6	2.1	24	24.6	3.0	24	35.1	5.7	23	65.6	12.3	24	144.2			
7	3.	25	35.8	3.8	24	44.5	6.2	24	72.6	8.2	24	96.1			
8	2.7	26	32.8	3.6	24	42.2	8.2	24	96.1	9.2	25	109.8			
9	1.6	26	19.4	3.8	25	45.3	10.8	25	128.9	9.9	25	118 1			

LOCATION OF STATIONS

Station A—Near the creamery sewer outlet.
Station B—500 feet west of Station A.
Station C—500 feet northwest of Station B.
Station D—500 feet northeast of Station C.
Station E—1,000 feet east of Station D.


HOURLY VARIATIONS IN DISSOLVED OXYGEN
CLEARWATER LAKE, WACONIA, MINN.
JULY 22-23, 1932
LEGEND
STA. A
STA. B
STA. C
STA. D
SUNRISE
SUNSET
DISSOLVED OXYGEN - PER CENT SATURATION
500
250
200
150
100
50
0
A.M.
P.M.

CERTAIN MINNOWS SHOWING ADAPTABILITY TO CONDITIONS IN IMPOUNDED WATERS

EMMELINE MOORE

Chief Aquatic Biologist, New York State Conservation Department

My brief paper adds a mere crumb of information to the subject of minnows that show adaptability to conditions in artificially developed lakes.

The fisheries survey studies conducted in New York waters have disclosed the presence and wide distribution of numerous species of minnows in ponds and reservoirs. A few of them show evident adaptability in these situations From the records I have selected three species for emphasis because of their special significance as forage fishes in these large reservoirs. They are the golden shiner (*Notemigonus c. crysoleucas*) a versatile species tolerating a wide range of elevation; the blunt-nosed minnow (*Hyborhynchus notatus*) generally distributed in lowland, warm game fish waters; and the fat-head minnow (*Pimephales p. promelas*) an upland species which may reach a high concentration in ponds and reservoirs if too many other species are not in competition with it. Each of the trio is predominantly a plankton feeder and that is one of the biologic fundamentals which should determine a choice for experimental purposes in reservoirs with considerable fluctuation in level. All are excellent food minnows. The fat-head and blunt-nosed have the valuable characteristic of a prolonged spawning period producing a yield of young fishes throughout the summer season.

Observations of the adaptability of these minnows cover examples among reservoirs that have age and maturity and those that are young and newly made. One of our oldest upland storage reservoirs, Cranberry lake, was constructed 65 years ago. It has been and is still a notable speckled trout water. Our records show that the fat-head, a native also of the lake, has held its own apparently in favorable balance with the trout which feed upon it. The subsequent introduction of the golden shiner now in the reservoir seems likely to complicate the further record history of the fat-head in this situation. The blunt-nosed minnow was observed in Rockville reservoir of the Genesee drainage, where a high concentration of this species was noted and its spawning habits studied by Mr. J. R. Greeley of the survey staff.

In our newest and largest reservoir, the Sacandaga, now in its third year, the golden shiner has developed a notable yield. From the catches taken during the survey this summer by Mr. T. T. Odell and others of the survey, its rating was given as abundant. A single gill-net catch set in the marginal shallows produced a haul of about

500 specimens nearly all of which were mature. The examination of 150 of them showed they were subsisting chiefly on animal plankton. In consideration of the brief space of time since the reservoir has been in existence, this is a positive achievement in natural reproduction. The reservoir when full has an area of 26,700 acres and a possible fluctuating level of 30 feet. The minnow was self-stocked from the flooded waters of the basin.

A practical need is shown by the study of another of our large and older storage reservoirs—the Fulton chain. In this impounded water predatory species of the warm water game fish varieties have overrun a former trout water with consequent depletion of the forage species. The studies of the fish inhabitants disclose the absence of a strictly plankton feeder to provide, as it were, the steadying influence in the economy of the lake. A good choice in view of the circumstances is the blunt-nosed minnow which has been recommended because of its association normally with warm water game fishes now domiciled there.

When one's curiosity extends to that great project, the Hoover dam on the Colorado river, and the vast volume of water to be impounded within the canyon, it is interesting to reflect upon the pattern of fish life that may develop there. There seems no doubt there will be a plentitude of plankton and that this should determine the stocking technique.

In the developmental history of our natural lakes it has required many generations in time to produce a stable balance. Storage reservoirs unlike them are less a going concern. Yet in such reservoirs along with notable liabilities there are notable assets in the balance sheet. The follow-up studies on the Sacandaga confirm this. To review briefly the debit side, on the drowning of a valley the bottom layers at once become stagnant due to the decomposition of flooded vegetation and its incident animal life. The gaseous relations in consequence of this, show an abnormally low oxygen supply, a condition likely to persist indefinitely. Weed beds if established at all will always be meager. Fluctuations in level cause an indefinite but persistent loss. On the credit side, there is provided an enormous volume of good water in the upper levels and in the marginal shallows. There is a continuous and enormous yield of plankton, that free-floating, minute microscopic stuff, which bulks large as a basic food resource in the economy of such waters.

How then does the situation lend itself to scientific management and to the economical production of fish? Dealing only with one aspect of the problem, the stocking with a suitable minnow, a selection should be made from an "income producing" species, i. e., from a plankton feeder of which the golden shiner, the blunt-nosed and the fat-head are outstanding species that can tolerate the vicissitudes of reservoir life and relish the endless monotony of plankton with which to fill themselves.

THE UTILITY OF NETS IN FRESH-WATER PLANKTON INVESTIGATIONS

W. E. RICKER

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Last year Dr. R. E. Foerster, Director of the Pacific Salmon Research Station at Cultus lake, B. C., outlined to the members of the American Fisheries Society something of what had been accomplished during six years of research at that station. His investigations have revealed in the case of sockeye salmon that the numbers which die in fresh-water are extremely large. In two years when fry have been distributed into Cultus lake from the hatcheries, only four to six per cent of these have appeared at the outlet in the following spring to run to the sea; the remainder have all apparently perished in the lake. Accordingly, in 1932 an attempt was made to learn something of the habits of the fry and fingerlings in the lacustrine phase of their existence. Since the young sockeye of Cultus lake feed almost exclusively upon plankton crustacea, a careful investigation of the seasonal variation in numbers of these organisms was especially desirable.

At the start, consideration was given to three kinds of apparatus for obtaining plankton samples: namely, nets, pumps, and traps.

(1) *Nets.* Plankton nets have been in use from the earliest days of limnological study, and were first employed quantitatively on this continent by Dr. Birge of Wisconsin, the results of whose studies upon the crustacea of Lake Mendota were published in 1897. Nets have an advantage over other methods of collection by reason of their lightness and ease of operation, particularly when only small craft—rowboats or canoes—are available. Further, a net strains a *column* of water, rather than taking a sample at a point, and hence, theoretically at least, will give a better picture of the average numbers of organisms between any two levels than will a trap.

Unfortunately a net offers resistance to the passage of water through its meshes and so does not strain the total volume of water through which it is drawn. Hence if calculations of the actual numbers of plankton populations are to be made from net hauls, the net must first be standardized by comparison with some other kind of collector. Even when so standardized, a net's efficiency may vary from day to day, or throughout a series of hauls, or even in the course of a single haul, by reason of shrinkage, fraying, or clogging of its meshes.

(2) *Pumps.* Pumps have decided advantages as plankton collectors. Relatively large quantities of water can be used so that an abundant catch is always assured, and it is easy to determine how

much water is being filtered. A pump may be used to collect the plankton at a given level, in the manner of a trap, or throughout a column of water, after the fashion of a net. Reighard (1898) casts doubt upon the pump's ability to obtain a uniform vertical water sample, but could give no reason for his skepticism.

More cogent are the remarks of Birge and Juday (1922), who say: "The chief objection to a pump is that the currents produced in the water at the intake end of the hose tend to drive away the more active planktons that are negatively rheotropic. Several sets of experiments made with a plankton trap and the power pumps showed an advantage in favor of the trap of 16% in *Diaptomus* and of 15% in *Daphnias;* on the other hand, there was numerical advantage in favor of the power pumps amounting to 12% in *Cyclops* and 27% in the nauplii." (*Cyclops* and the nauplii, unlike their larger relatives, must evidently be positively rheotropic.) Other objections are that pumping apparatus is rather unwieldy and slow in operation, usually requiring the attention of two workers.

(3) *Traps.* Plankton traps are usually brass cylinders with closing ends, which surround a known volume of water at any desired depth and bring it to the surface, where it may be filtered through a net. Thus Birge and Juday's objection, quoted above, is non-existent. Many traps are, however, so small as to yield only meagre catches; those large enough to give a representative sample are too heavy to be handled from a small boat. Traps also differ from nets in that they take the plankton at given points, rather than through a given range. For example, in doing a vertical series with a trap, samples would be taken at the surface, at say five meters, ten meters, fifteen meters and so on; with a net samples may be taken from the surface to five meters, five to ten meters, etc. To obtain with a trip the equivalent of one total vertical net haul, many samples must be taken, from top to bottom.

Size and Design of Nets Used at Cultus Lake

The above considerations seemed to indicate that nets were the plankton apparatus most practical for use on Cultus lake, and accordingly two standard types were adopted. The first type was modelled after the "small net" described by Juday (1916, p. 569) but the truncated cone of canvas was made 25 cm. long so that it could be used as a closing net. This net, referred to as a "Juday net" throughout this paper, is, however, not the same as Juday's closing net, or "Wisconsin Net," (loc. cit. p. 573) which had the same aperture but longer cones. The silk cone and bucket when new had a straining area 1.13 times that of the accurate Juday measurements, but after eight months of use it had shrunk to 0.95, or 16% of its original size. A second Juday net was made in August of this year. When new its straining area was 1.14, after being soaked and dried it shrank to 1.05, and after being used to take ten forty-meter hauls

it was still 1.05 of a standard Juday. The second type of net used on Cultus lake was designed by Dr. D. S. Rawson of the University of Saskatchewan. It has much the same shape as the Juday net, but most of its linear dimensions are 2.5 times as great. On most lakes it will take, in one total vertical haul, enough plankton for a Micro-Kjeldahl nitrogen determination. Its catches have been used for that purpose almost exclusively.

All of these nets were made of number 20 Swiss silk, and carried buckets of the standard pattern.

Calibration of Nets

For calibrating the nets a Bunwell No. 1 wing pump was used, attached to forty meters of three-quarter-inch hose. When worked at the rate of one complete stroke (back and forth) per second, its delivery was 0.218 litres per stroke. In making a total vertical haul with the pump, some care was needed to make certain that the sample would be uniform from top to bottom. The empty hose was first lowered to 0.5 meters from the bottom, filling as it went. The pump was primed with plankton-free water, then the hose connected to the pump. Attached to the lower end of the hose was a windlass cable, by means of which it was now hauled upward at a constant rate, 0.3 meters per second in most of these experiments, and at the same time the pump was started. At the end of a haul the hose was looped hand over hand so that all of its water flowed down through the pump and into the net. The water pumped up was filtered through a Juday net suspended in the lake from the side of the boat. Catches taken in this manner can be compared directly with total vertical net hauls taken at or near the same time.

When phytoplankton is abundant in a lake, there is a possibility that a net's efficiency may rapidly decrease in the course of a haul, because its meshes become choked with plant colonies and filaments. The author has had no opportunity to test this supposition, because all of the standardization work to be described was done at times when the quantity of phytoplankton retained in the net was relatively small: the number of colonies of *Asterionella,* much the most abundant plant, never exceeded a thousand per liter. Of the animals, rotifers were very scarce, and *Dinobryon,* the only other common organism, equalled *Ceratium* in July, but declined rapidly thereafter. It is apparent that clogging of their meshes can have had little influence upon the efficiency of the nets used.

Errors in Enumeration of Planktons

Enumeration of the larger organisms in a plankton catch is accomplished by transferring it to a special cell under a binocular microscope. The cell used in this work had an area of twenty-five square centimeters and a capacity of five cubic centimeters; its glass bottom was

ruled into twelve equal columns. In counting, the eye travels slowly up and down these columns as the cell is moved on the microscope stage. Even under most favorable conditions the process is a laborious one. Accordingly, many workers have lessened its tedium by counting only a fraction of each catch, e. g., Birge (1897), who used one-quarter to one-fifteenth of a haul.

In most of the work at Cultus lake, catches have been diluted to twenty cubic centimeters, and a five cubic centimeter sample removed in a special broad-mouthed pipette. The accuracy of this method was checked by counting ten separate samples taken from the same catch, and the results were surprisingly discrepant. In the case of even the most common organism, *Cyclops,* the highest count was one-third greater than the lowest (Table 1). A similar test was made using one of the Rawson net catches. In this case the catch was diluted to fifty cubic centimeters, and two cubic centimeters removed for counting by means of a medicine dropper. The results were much the same. The highest count, in the case of the abundant organisms, was about four-thirds of the lowest; in the case of the rare *Epischura* the highest was three times the lowest. It is clear that the accuracy of fracional counts is strictly limited. In most of the work which follows, counts of whole catches have been made in order to avoid this source of error.

Change in Efficiency With Rate of Hauling

Another point to be established was the effect of the rate of hauling a net upon its efficiency. Accordingly, on July 4, 1932, six forty-meter hauls were made in succession, two each at 0.25, 0.5 and 1.0 meters per second. The net was washed with soap, but not dried, between hauls. As it had previously been used to take a long series, its efficiency was assumed to have reached a constant level (see below). A fractional count was made on each haul, with this result:

At 0.25 m./second the net caught 384 *Cyclops* plus 120 *Daphnia*=504 animals
At 0.5 m./second the net caught 416 *Cyclops* plus 200 *Daphnia*=616 animals
At 1.0 m./second the net caught 744 *Cyclops* plus 232 *Daphnia*=976 animals

The standard rate of hauling, adopted by limnologists almost universally, has been 0.5 meters per second. The figures above show that, if an important source of error is to be avoided, it is necessary to adhere closely to this figure. It is also a noteworthy fact that the half-meter per second rate is apparently not as efficient as a faster rate of haul, at least under the conditions prevailing when these hauls were made, i. e., with phytoplankton of all kinds very scarce.

Change in Efficiency Throughout a Series of Hauls

On July 4, 1932, ten total vertical hauls were taken at intervals of ten minutes at a permanent station in the middle of the lake, forty meters in depth. Between each haul the net was washed with soap and water, but was not allowed to dry. Counts were made of one-quarter of each sample, as shown in Table II. They indicated that in spite of washing, the efficiency of the net fell off throughout the

course of the series. Since all hauls were taken in the same spot, there was a possibility that this was a result of a local depletion in numbers of the organisms counted.

The test was repeated on July 23, a calm day, when it was possible to take a series of ten hauls at points twenty to one hundred feet apart, but all within one hundred feet of the buoy. The whole of every haul was counted, with the results shown in Table II. With no possibility of depletion and with counting error eliminated, these hauls show an even wider spread of numbers than the former series, and, like it, show that the efficiency of the net decreased while the ten hauls were being taken.

The variation in numbers of organisms caught by a freshly-wetted net is not as great as this. Ten hauls were taken on September 2, a clear, windy day. After each haul the net was allowed to dry for twenty-five minutes, then was washed with soap before the next. The counts show no sign of the decrease in efficiency characteristic of the two wet-net series.

In routine practice, nets are not allowed to dry between hauls when a series is being taken. Hence a gradual decrease in efficiency is bound to occur, and results will be correspondingly unreliable. Whether or not this decrease would continue indefinitely if more hauls than ten were to be taken, is not clear. The form of a curve plotted from these data suggests that the efficiency would asymptotically approach a lower limit, which for practical purposes has been reached at the end of the tenth, or even the fifth, haul.

Change in Efficiency of a Net Throughout a Season

On October 4, 1932, a series of ten hauls each was made with a new Juday net and an old one. The new net had been soaked and dried several times but had never been used to capture plankton. The old net had been in use since January 15 of the same year, during which time it had been hauled roughly 4,000 meters in the taking of bi-monthly plankton samples. Both were washed prior to every haul of this series. Comparison of the net factors deduced from the counts of four organisms (Table III, third trial) indicates that the new net was 2.8 times as efficient as the old. When a net will deteriorate so rapidly, a single determination of its "factor" can be of little use. It is apparently necessary to standardize fairly often if its catches are to be used quantitatively.

Absolute Efficiency of the Nets

Three attempts were made to determine the "absolute" efficiency of the Juday net, which may be defined as the ratio of the volume of water actually strained by the net to the volume of water through which it is hauled. The reciprocal ratio is known as the net factor or coefficient, and is the factor by which a net's catch must be multiplied to give the number of organisms actually present in the

water. On July 22, two total vertical hauls were taken with the pump, and their counts compared with ten "wet-net" hauls taken at the same place on the following day.

On September 1, ten "pump" hauls were taken and checked with ten "dry-net" hauls made September 2. In the last case, 40.4 liters of water were strained in each of the pump hauls, through the Juday net suspended at the surface. Total counts were made of *Epischura, Cyclops* and *Daphnia,* and a fractional count (1/10) of *Ceratium.* The numbers of these organisms per cubic meter were then calculated by dividing by 0.0404. Similarly the numbers of organisms taken by the net were divided by 0.453—the net, being twelve centimeters in diameter at the mouth, could, if it offered no resistance to the passage of water, strain 453 liters in a forty-meter haul.

On October 4, a still more instructive series was taken: ten hauls each of the pump, the old Juday net No. 1, and a new Juday net No. 2. Hauls were taken in rotation: pump, net 1, net 2, and counts were made in the same fashion. Results were treated as in the preceding trial, but unfortunately one haul with each device contained bottom mud, and was thus useless. The day was clear throughout, slightly windy in the morning but calm later. Nets could be dried between the first five hauls of each series, but the last five were with wet nets and consequently showed a marked falling off in efficiency which is not apparent in the pump hauls.

Counts made in all three trials were set forth in Table II. Assuming for the moment that the pump is 100% efficient as a collector of all types of larger planktons, the numbers of organisms per cubic meter, taken by net and pump, have been compared directly, and the net factors so obtained are presented in Table III. The important conclusion to be derived from a study of the table is that these nets are unexpectedly inefficient. The catch of even the new net is only 18% of the possible number (factor 5.6), i. e., the net strains less than one-fifth of the column of water through which it is hauled. The old net strains much less again: only one-fourteenth of the possible quantity (factor 14.4).

In comparing these figures with those obtained by other workers, much difficulty arises from the variety of nets in use. Most important are differences in (1) style of net, whether a simple cone or with the additional truncated cone of cotton, (2) the straining fabric used, and in (3) the ratio of mouth aperture to straining area, a high ratio being indicative of less efficient construction. Birge (1897), using simple cones of either muslin or No. 16 silk, obtained factors of 1.9-2.0. Kofoid's (1903) smaller net of the finer and more usual No. 20 silk, and more efficient construction, obtained ratios between 1.5 and 5.2. Kofoid believed that his net's failure to attain to a theoretical factor of 1.32, calculated from the formulae of Hensen, was the result partly of shrinkage with use, but chiefly of clogging by silt and by planktons in the course of each (30 meter) haul. Juday

(1916) claimed for his Wisconsin net a factor of 1.2 ("efficiency of about 80%") and used this figure in his studies upon Lake George and the Finger lakes of New York. Recently, however (1932) he mentions a similar net with factor between 1.8 and 2.0. Kemmerer et. al. (1923) also had a Wisconsin net with the factor 1.2, but whether they determined this independently or accepted Juday's figure is not clear. MacKay (1924) records two nets, apparently of similar construction, whose factors he determined as 1.5 and 1.2. Rawson (1930) mentions one having factor 1.6, determined "at the end of the first season."

Of this array, the early results of Birge and Kofoid, and possibly Juday's most recent figure, are in fairly close agreement with the factors obtained in the present investigation, if the differences in the nets used are considered. But even allowing for the fact that the Wisconsin net is of somewhat more efficient proportions than the Juday net of this paper, it is extremely difficult to reconcile the findings of Kemmerer, MacKay, Rawson, and Juday (1916) with what has transpired in the research upon Cultus lake. Some significance may attach to the fact that all of these last-named investigators used the trap method of standardization. In that case they could haul their nets through only a short column of water—MacKay and Rawson both used a one-meter haul. It may be that for some reason not readily apparent a net is much more efficient in a very short haul than in a longer one. But there is other evidence to show this is not the case (e. g., see Birge, 1897, p. 284).

We must now rather belatedly examine the criticism which Birge and Juday levelled against the use of a pump for purposes of standardization. Examination of Table III reveals that the third trial gives only slight indication that any one of the three crustaceans counted is either positively or negatively rheotropic. With the possible exception of *Cyclops* in the old net, there is no case where the difference in relative abundance between the active organisms and the non-motile *Ceratium* exceeds a reasonable statistical expectation. However, since nearly all of the entomostracan factors are somewhat higher than the corresponding *Ceratium* factor, it may be that these organisms can, in vigorous efforts, slightly improve their chances to escape being sucked up into the pump, i. e., are negatively rheotropic.* But this movement, if it does exist, is apparently not significant enough to greatly impair the value of these counts for standardization purposes.

In the *second* trial, Table III, very significant differences between

*Another explanation of this phenomenon may be offered, based upon a supposed activity of the organisms during the *net* haul. While a net is being drawn up, water is pushed aside, creating a steady current *away from* its mouth. Hence animals negatively rheotropic would tend to appear in the catch in numbers relatively too great, and vice versa. Assuming *Cyclops* to be positively rheotropic (As Birge and Juday imply), there is thus a possible reason for the large *Cyclops*-factor mentioned above. The same assumption might indicate why the discrepancy in the case of the new net was not as great as in the case of the old; being more efficient, the new net created less of an outbound current.

the factors obtained with *Ceratium* and those with two of the active organisms, are readily apparent. Such is their magnitude that the tropistic theory offered above is quite inadequate to explain them. They indicate rather that the plankton population at a given station may change rapidly from day to day, owing partly to births and deaths, but mostly to migration and water movements. Since the pump and net hauls in the second trial were on successive days, we may infer that the water near the buoy doubled its quota of *Epischura* and lost half of its *Daphnia* overnight. In the case of the first trial, both of these organisms apparently increased in the twenty-four-hour period. There seems no escape from such an assumption, which amounts to an admission of very unequal horizontal distribution of these organisms throughout the lake at any time. This is additional to the more restricted, but still large, fluctuation evident in a series of dry-net or pump hauls from one spot. Thus one more hazard is added to attempts at enumeration of plankton populations, by any method.

In selecting the best single value of the net factor for each of the cases in Table III, there were three courses open: (1) To ignore the questionable crustacean figures and accept the value given by the counts of the practically non-motile *Ceratium*; which counts are however probably less dependable than the others, because of the animal's small size; (2) to add up the total number of organisms of all kinds that were actually counted from the pump and net hauls, then divide; this method would allow any extra activity on the part of the abundant *Cyclops* to affect the result unduly. (3) To average the four factors, weighting each inversely as the square of its probable error—a common procedure, whose application in this case was perhaps hardly justified. Whatever value may be preferred they all agree closely enough to support the conclusions presented earlier in this section.

SUMMARY

1. Fresh-water plankton organisms may be most easily captured by using a silk net; and such nets, rather than pumps or traps, have always been used whenever portability or ease of operation have been important considerations. Unfortunately, there are many sources of error in the use of a net, whose magnitude may be expressed in terms of the statistical *probable* error (p. e.), and the *possible* error, which is here defined as the greatest percentage deviation from the mean observed in ten counts.

2. A net made of No. 20 silk should be wetted and dried several times before being used in order to shrink the threads. If this is done, subsequent shrinkage will be relatively slight.

3. When one count is made of a fraction of a haul, a measure of the inaccuracy which may be expected to be introduced by this pro-

cedure is given by a p. e. of ±7 (for a single count), possible error of 20%, when about 100 organisms are counted.

4. The rate at which a net is hauled has an effect upon the abundance of its catch, the catch increasing as the rate rises, at least as far as 1 m./sec. Investigators should adhere closely to some standard rate, 0.5 m./sec. being usually adopted.

5. If a net be used for a series of hauls, and be not dried thoroughly between each, then its efficiency will fall off throughout the series, rapidly at first and more slowly later. Its efficiency will reach a fairly constant value after about five hauls, at a level which is between two-thirds and one-half of its original efficiency. In such a "wet-net" series, a count of 100 may have a p. e. of ±16, possible error of 35%.

6. When a net is dried thoroughly between hauls, no such decrease in efficiency is evident. A count of 100 made in a series of dry-net hauls will have a p. e. of ±7, possible error of 20%. Since the pump hauls have about the same accuracy, it is probable that these errors are the result of irregular local distributions of the larger planktons.

7. There is evidence that over wider areas certain planktons may be of more scattered horizontal distribution, so that if a sample is to be considered representative of the entire pelagic biota of the lake, the possible error from this cause will be at least 50%.

8. When a plankton net is used to take a short series of hauls every two weeks, its efficiency may be expected to decline to about two-fifths of its original value after ten months of service.

9. The efficiency of two small plankton nets was carefully determined by comparison with pump catches. A new net was found to be 18% efficient; an old net of the same design was only 7% efficient.

10. Many writers of papers dealing with plankton quantitatively have not known or not emphasized the limitations of a net's utility cited above, and their work leaves the impression that too much confidence has been placed in its numerical accuracy. Figures obtained from the catches of pumps or large traps are undoubtedly superior to net figures. If local considerations indicate that a net must be used, it should be standardized frequently.

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TABLE I.—VARIATION IN COUNTS OF A SINGLE PLANKTON HAUL MADE BY THE DILUTION METHOD

Date 1922	Fraction Counted	Organism	Count Number										Ave.	P. E. of the ave.	P. E. of an individual count
			1	2	3	4	5	6	7	8	9	10			
July 4	One-fourth	*Epischura*	1	1	4	4	1	2	2	4	2	3	2.4	±0.27	±0.55
Juday Net		*Cyclops*	163	179	198	184	155	173	166	186	207	174	178.5	±3.4	±10.7
		Daphnia	62	75	65	86	75	89	65	86	86	78	67.4	±2.1	±6.7
July 22	One-twenty-fifth	*Epischura*	4	5	7	5	6	8	3	3	9	5	5.5	±0.43	±1.4
Rawson Net		*Cyclops*	144	160	129	139	129	134	138	125	119	127	134.6	±2.5	±7.9
		Daphnia	54	50	46	45	41	54	52	52	42	46	48.3	±1.1	±3.3

TABLE II.—NUMBERS OF ORGANISMS IN CULTUS LAKE PLANKTON. TOTAL CATCH COUNTED, EXCEPT AS NOTED

		Count Number												
	Organism	1	2	3	4	5	6	7	8	9	10	Ave.	P. E. of the ave.	P. E. of an individual count
July 4, 1932	*Epischura	4	0	0	0	8	0	0	0	0	8	2.0	± 0.73	± 2.3
Net washed between hauls	*Cyclops	652	564	568	496	424	444	436	420	424	408	484	± 17.7	± 56.
	*Daphnia	248	240	232	148	164	180	144	128	176	228	189	± 9.5	± 30.
July 23, 1932	Epischura	16	16	13	5	14	14	7	14	9	12	12.0	± 0.80	± 2.5
Net washed between hauls	Cyclops	575	721	610	413	450	346	322	403	397	382	462	± 27.	± 86.
	Daphnia	225	276	225	239	240	213	190	133	151	152	204	± 9.9	± 31.
September 2, 1932	Epischura	12	5	6	8	8	8	7	4	4	10	7.2	± 0.55	± 1.74
Net washed and dried between hauls	Cyclops	487	452	417	460	546	514	392	483	530	499	478	± 10.4	± 32.8
	Daphnia	37	48	37	46	38	38	50	33	35	50	41.2	± 1.40	± 4.42
	†Ceratium	1690	1490	1430	1590	1520	1520	1600	1400	1490	1920	1565	± 32.2	±102.
September 1, 1932	Epischura	3	5	8	4	3	4	1	2	0	4	3.4	± 0.47	± 1.50
Pump Hauls	Cyclops	545	634	495	691	592	575	622	585	615	635	599	± 11.5	± 36.5
	Daphnia	110	56	94	82	84	72	89	63	87	79	81.6	± 3.30	± 10.4
	†Ceratium	1190	1720	1630	1420	1580	1600	1460	1130	1390	1320	1444	± 41.	±130.
October 4, 1932	Epischura	4	2	5	2	0		2	1	4	0	2.2	± 0.40	± 1.21
Pump Hauls	Cyclops	595	548	494	559	626		552	554	429	485	539	± 13.3	± 39.8
	Daphnia	11	8	9	4	11		11	6	13	6	8.8	± 0.67	± 2.02
	†Ceratium	1280	1660	1660	1180	1640		1600	1470	1900	1960	1590	± 57.6	±173.
October 4, 1932	Epischura	2	0	1		1	2	2	0	0	1	1.0	± 0.19	± 0.58
Net No. 1 (old)	Cyclops	295	342	476		292	261	247	331	234	262	304	± 16.6	± 49.8
	Daphnia	9	5	12		7	12	9	12	5	7	8.7	± 0.65	± 1.94
	†Ceratium	1300	1620	1520		950	860	1260	1650	1570	1550	1360	± 66.0	±198.
October 4, 1932	Epischura	5	9	8		5	7	7	5	4	3	5.9	± 0.66	± 1.97
Net No. 2 (new)	Cyclops	1332	1144	1008		1102	794	962	767	622	686	935	± 52.9	±159.
	Daphnia	29	28	17		20	14	24	12	9	15	18.7	± 1.59	± 4.77
	†Ceratium	4980	3800	3750			3120	3020	3380	3300	3250	3580	±150.	±426.

*Only one-fourth catch counted.

†Only one-tenth catch counted.

TABLE III
SUMMARY OF PUMP AND NET CATCHES OF PLANKTON ORGANISMS, AND NET FACTORS DEDUCED THEREFROM

Organism counted		Pump	Net No. 1 (Old)		Net No. 2 (New)	
		Number of Organisms per cubic meter	Number of Organisms per cubic meter	Factor P/N	Number of Organisms per cubic meter	Factor P/N
Date		July 22, 1932	July 23, 1932			
	Epischura	117	26.5 ± 1.77	4.6		
First	*Cyclops*	11,770	1,019 ± 59.	11.6		
Trial	*Daphnia*	3,240	450 ±	7.2		
Date		Sept. 1, 1932	Sept. 2, 1932			
	Epischura	84 ± 11.6	16 ± 1.2	5.3 ± 0.83		
Second	*Cyclops*	14,820 ± 284.	1,056 ± 22.9	14.0 ± 0.41		
Trial	*Daphnia*	2,020 ± 81.7	91 ± 3.1	22.2 ± 1.16		
	Ceratium	35,800 ± 1,020.	3,460 ± 71.2	10.3 ± 0.36		
	Weighted Average			11.8 ± 1.05		
Date		Oct. 4, 1932	Oct. 4, 1932		Oct. 4, 1932	
	Epischura	54 ± 9.9	2.2 ± 0.42	25. ± 6.6	12.6 ± 1.41	4.3 ± 0.92
Third	*Cyclops*	13,340 ± 329.	672 ± 36.7	19.9 ± 1.19	1,998 ± 113.	6.7 ± 0.41
Trial	*Daphnia*	218 ± 16.6	19.2 ± 1.43	11.3 ± 1.20	39.9 ± 3.39	5.5 ± 0.62
	Ceratium	39,350 ± 1,430.	3,000 ± 146.	13.1 ± 0.79	7,640 ± 320.	5.2 ± 0.28
	Weighted Average			14.4 ± 1.30		5.6 ± 0.28

NOTES ON THE OCEAN FEEDING GROUNDS OF THE ATLANTIC SALMON

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The Atlantic salmon in Canada leaves its native river for the ocean when two to five years old. It remains in the ocean for one, two, three, or even four years before it returns to the fresh water for spawning. Practically nothing is known concerning its existence during the period of ocean life, and few records of salmon other than on the spawning migration have been obtained.

Various theories based on isolated captures and occasional observations have been formulated relative to the feeding grounds and migrations of the salmon in the ocean. It has been assumed that salmon follow the food supply, which largely consists of herring, sand eels, smelt, and other small fishes, that they travel long distances in search of food, and that the salmon of the British Isles and Europe mingle with the salmon of northeastern America. It has also been maintained that the salmon remain near the mouths of their respective rivers and do not go beyond the coastal waters. This paper presents indirect evidence which throws some light upon the question of whether the salmon of Europe and America occupy the same feeding grounds in the ocean.

Material: The data were obtained from the careful records of the salmon taken by anglers in three rivers: the Godbout on the north shore of the St. Lawrence, the Restigouche at the head of the Bay of Chaleur, and the Wye in England. In the two Canadian rivers the records, which were furnished through the courtesy of the Restigouche Salmon Club and of the lessees of the Godbout river, give the weights of the individual salmon. Scale reading indicates that in Canadian rivers the two-winter sea life salmon can be separated with great accuracy from the three-winter and previously spawned salmon by graphic methods. This is possible because of the uniform size of the two and two-plus winter sea life salmon during the brief angling season, a condition which is impossible in England where, with a long season, there is a wide range in the size of the 2+ winter sea life salmon. When the two-winter sea life salmon have been separated, it is possible to obtain the average weight of several hundred salmon for each year.

Exact records of the Wye salmon from 1909 to 1928 through the extensive and painstaking scale reading studies of J. A. Hutton have been published in a series of articles in the *Salmon and Trout Magazine.* From these valuable contributions the average annual weights of the two-winter (small spring) group of salmon have been ob-

tained. This group has ben selected because of its more limited season and because it most nearly approximates the Canadian two-winter sea life salmon.

Weight: The weight of the salmon depends upon its size (length) and upon its condition (fatness and shape). The shape of the salmon, which in general is characteristic for each river, may be disregarded in comparing different years in the same river. Since over two-thirds of the growth of the two-winter sea life salmon takes place during the second year, its weight (size and condition) is an index of the food supply and feeding conditions in the ocean during the year previous to the spawning migration.

Annual Fluctuations in Weight: The weight of the two-winter salmon shows marked annual fluctuations, indicating that the feeding conditions vary from year to year. If the salmon of the three rivers were subject to the same feeding conditions, i. e., occupying the same feeding grounds, these annual fluctuations would follow the same trend. If feeding conditions were different for the three river groups, no similarity would appear.

A comparison of the yearly weights for these three rivers from 1909 to 1928, a period of twenty years, is given in the accompanying table and is graphically represented in Figure 1. Barring minor irregularities, probably of technical origin, the yearly fluctuations of the Godbout and the Restigouche salmon are strikingly similar, indicating that the salmon of the two Canadian rivers, though situated in different geographical locations, occupy the same feeding grounds in the ocean, or at any rate are subject to similar feeding conditions. On the other hand, the fluctuations of the Wye salmon do not agree with those of the Canadian rivers, indicating that the feeding conditions are different.

Conclusion: This evidence, though indirect, adds to the few tangible facts which are on record relative to the ocean habitat of the salmon. It is evident that the Canadian and English salmon are not subject to similar feeding conditions and consequently do not occupy the same feeding grounds. If they do not occupy the same feeding grounds, the salmon of the two countries do not mingle in the ocean and probably remain on their respective sides of the Atlantic Ocean.

AVERAGE YEARLY WEIGHT OF TWO-WINTER SEA LIFE ATLANTIC SALMON

Year	Rivers		
	Wye	Restigouche	Godbout
1909	10.1	9.65	8.24
1910	9.8	10.48	8.92
1911	10.9	10.90	9.40
1912	10.7	10.98	9.24
1913	11.6	11.09	9.04
1914	11.9	10.29	8.59
1915	11.9	9.62	8.82
1916	12.3	11.28	9.49

1917	11.5	10.66	8.72
1918	11.1	11.53	9.31
1919	10.8	10.28	8.54
1920	11.2	9.72	8.21
1921	11.4	10.73	9.21
1922	10.4	11.18	9.08
1923	11.1	10.98	9.58
1924	11.3	12.31	9.45
1925	11.9	12.51	9.64
1926	10.6	11.08	8.34
1927	12.3	10.44	8.80
1928	10.4	10.45	8.63
Yearly average for 20 years	11.2	10.81	8.96

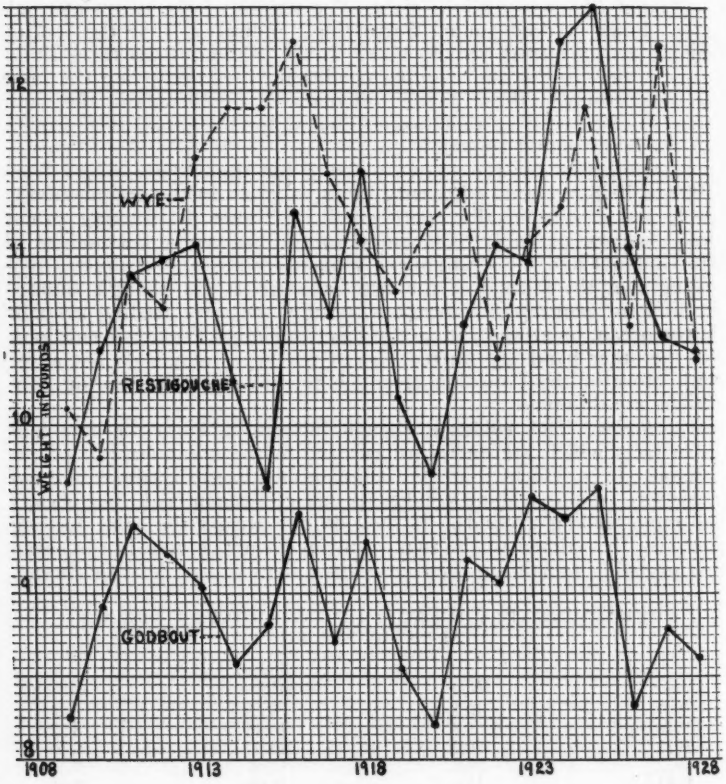

Fig. 1.
Comparison of average yearly weight for the two-winter sea life salmon of the Godbout, Restigouche, and Wye Rivers.

FISH POPULATION AND PRODUCTIVITY OF LAKES

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When the fisheries resources of a certain body of water are over exploited and the industry after reaching its maximum begins to decrease, it is necessary to make detailed investigations in order to find means for preserving the industry and keeping it in a healthy condition.

The main problem of such investigations is to determine those specific conditions under which productiveness on one side and resisting forces on the other keep the fish population in balance.

The total quantity of commercial fishes of a lake we can divide into two large groups: (a) fishes which have reached commercial size, and (b) fishes less than this size. It is not sufficient to investigate only individuals of the first group, i. e., adult commercial fishes, the total amount of these being dependent very often not so much on the intensity of fishing and over-fishing as on the regularity and constancy with which their numbers are augmented every year by individuals from the second group. And here, the main problem of the investigations is the study of the conditions which regulate the total amount of young fishes. Two factors are at work here, (1) quantity of fertilized eggs, and (2) the mortality of eggs and fry. It is very easy to understand that the intensity of fishing has no influence on the second factor, i. e., on mortality of fertilized eggs and fry, and can only cause a decrease in quantity of the eggs.

Therefore, examinations of hydrological and hydrobiological conditions, rates of growth and food of fry should be a first consideration. Detailed investigations of the most important commercial species must be carried on, in order to:

A.

1. Obtain data of total amount of fish food in the lakes.
2. Daily consumption of food by each particular species.
3. To find average number of fish which can feed in certain areas.
4. To estimate the fish population, i. e., approximate number of individuals of every commercial species.
5. To find average duration of life of each particular species.

B.

1. To estimate the number of fertilized eggs deposited by each species under natural conditions and their mortality.
2. To estimate the number of fry of each commercial species hatched every year under natural conditions and their mortality.
3. To find methods of protecting the fry hatched in the hatcheries from perishing.

Only after such investigations shall we be able to estimate the maximum amount of fish which can be taken from the lakes every year without lowering the balance of the fish population. Modern rational fisheries cannot exist without these scientific methods of estimation; the same as modern agriculture cannot exist without analogical estimation applied to animal husbandry.

Let us now see how we may solve the above-mentioned problems. Is it really possible to estimate such things as the total amount of fish food or total number of fishes in the lake, or even the daily consumption of food by any individual fish? We are far yet from a definite solution of all these approached questions, and the present paper is only an attempt to throw some light on them from a theoretical point of view.

No doubt we can estimate the total amount of plankton during certain seasons by different methods such as are already widely applied and described by many investigators. We can also more or less accurately estimate the number, weight and chemical composition of most bottom organisms and accuracy depends only on the number of dredges or other bottom samples. By analysis of the stomach content of any fish we can find exactly all the organisms on which this fish lives.

Now we come to daily consumption of food by fish. Let us suppose that certain species of fish during a certain period feed only at night, and are caught by means of gill nets at intervals throughout the feeding period. It may be assumed that the average stomach shows a half-fed condition, because those fish which are caught just after sunset will have empty stomachs and those caught just at sunrise will have full stomachs. Exactness will depend on the number of specimens examined. Such an estimate is perhaps open to criticism but is offered as a suggestion, subject to correction. One example of such a night feeder is the common whitefish (*Coregonus clupeaformis*). It has been found by the author on the basis of many hundreds of fish examinations that the daily consumption of food by whitefish in Manitoban lakes is from 9 to 10 gm. consisting mainly of amphipods, mollusks and different insect larvae (Bajkov, 1930). This will be 3.28 Kg. rough weight per year, which accords quite well with the average increase in weight of whitefish by 200 gm. per year. This amount of food may seem to be too small, but we must not forget that the fish expends very few calories for keeping up the normal temperature of its body, which is only 2°-3° C. over the surrounding water temperature. Of course the quantity of 3.28 Kg. we must count as a minimum, without including all the other food organisms, which the whitefish takes, such as *Oligochaeta, Hirudinea, Acarina,* larvae of *Odonata, Corixa* and other food of secondary importance, which cannot be estimated exactly, also some vegetable matter, decomposing pieces of food, detritus, humus, mud, and other stuff containing organic matter.

Another night feeder in Lake Winnipeg is goldeye (*Hiodon chrysopsis*). As goldeye is entirely a surface and plankton feeding fish and that in the stomachs of goldeye caught during the night period near the surface above the depth of several fathoms, often are found great amounts of deep water organisms such as *Daphnia longispina,* which come to the surface at night, show that the goldeye is mostly a night feeder.

Ling (*Lota lota maculosa*) is absolutely a night feeder also, due to the fact that they bite on a hook only at night.

During the examination of stomach contents of different fishes several circumstances, as daily vertical migration of certain food organisms, difference in amount of food during the different seasons, etc., should be taken into consideration.

Some of our fishes are probably only day feeders. Others, as practically all our rapacious species, pike, pickerel, perch, etc., are both day and night feeders. In such a case their daily consumption theoretically should be twice as much as only night or day feeders. In each particular case the daily consumption of food should be estimated separately.

Of course, we cannot estimate at the present time a daily consumption of food taken in the sea by certain species of Pacific salmon, but due to the fact that some of them increase in weight to reach in a few months several pounds, we can conclude that they may take a tremendous amount of food. There may also be some physiological difference in digestion.

As soon as we know the total amount of fish food in a given body of water and the seasonal daily consumption by each particular species we can easily estimate how many individuals can feed on certain areas. But here we meet with some difficulties in calculation. We do not know the actual number of useful commercial fish and also the number of competitors. If competitors are living under the same condition as commercial species and if they have the same rates of growth, the ratios between number of competitors and number of a given commercial species can be calculated from the proportion of them in our catches by seine or gill net. Anyway here we must know the total amount of fish in the lake. Several attempts have been made in this direction up to date and, as far as I know, nothing has been published in Canada or in the United States.

Such calculations have been used for estimating the number of fish in the Caspian sea. The accuracy of such calculations certainly is open to criticism, but I must mention this fact, when Prof. Th. I. Baranoff and K. K. Tereschenko calculated by their own method that the total number of Caspian bream (*Abramis brama*) near the delta of the Volga river in the year 1911 as 50,000,000, while A. N. Derjavin, using entirely different methods, estimated the amount as 53,000,000 (Derjavin, 1922). It is evident, therefore, that such accuracy is quite sufficient for our practical use.

To estimate the exact total amount of fish is of course possible only in comparatively small ponds, drained annually, when we know the total number of fry distributed artificially and their mortality, as for instance in certain carp culturing in Europe. Nevertheless, it is possible to estimate approximately the number of commercial fish of every species for each body of water, where regular industry takes place. This is possible only if we know the maximum age attained by the fish, the age of the fish in catches, and the constitution of the catches for a period of years, not less than the age of the fish. It is taken for granted that the numerical composition of the fish fauna remains constant during the time of investigation. It is necessary to add a reservation that we cannot estimate the total number of fish perishing every year under natural conditions.

In the case of whitefish in our Prairie lakes this does not invalidate our estimate, because there appears to be a very low mortality of the adult whitefish from epidemics and there are not many big fish which eat the young whitefish (not fry), also there are few chances that an adult whitefish will live until it dies naturally.

Therefore the following estimate gives us an idea only of those fish which will eventually be caught by the fishermen, i. e., the only important parts of the fish population from our point of view.

The total number of individuals of a given commercial fish, in a given body of water, is equal to the sum of a series of generations, the number of which equals the maximum age of this species with discount of those fish which were caught during this time.

The quantity which remains of each age group gives the catches of the following years, during which one generation after another will be destroyed. Therefore the number of fish in each body of water, where regular industry takes place, will be as follows:

$$X_n = C_n(1-y)+C_{n+1}(1-y-y_1)+(C_{n+2}(1-y-y_1-y_2) \ldots \ldots \ldots$$
$$C_{n+l-1}(1-y-y_1-y_2 \ldots \ldots \ldots y_{l-1}).$$

Where:

X_n=number of individuals at the beginning of the nth year.
l=maximum age of fish.
C_n, C_{n-1}, etc.=catches of following years.
y=per cent of fry hatched in nth years.
y_1=per cent of individuals of one year old.
y_2=per cent of individuals of two years old.
y_3=per cent of individuals of three years old, etc.

If we use this formula for estimating the whitefish population, in Lakes Winnipeg, Winnipegosis and Manitoba, it will consist of fourteen terms, if we take fourteen years as the period of whitefish life. The amount of older fish (somewhere about two per cent) we do not take into consideration. On the other hand, there are scarcely any fish less than three years old.

The direct determination of the age of a great number of indi-

viduals, obtained from Lakes Winnipegosis and Winnipeg, gives the following percentages of each group.

LAKE WINNIPEGOSIS				LAKE WINNIPEG			
Age (yrs.)	Average length (mm.)	Average weight	%	Age (yrs.)	Average length (mm.)	Average weight	%
3	350	1.4	5	3	325	1.3	2
4	390	1.8	10	4	380	1.7	6
5	420	2.3	24	5	420	2.3	20
6	450	2.5	16	6	450	2.5	17
7	480	3	10	7	480	3	16
8	500	3.3	7	8	500	3.3	15
9	520	3.7	6	9	520	3.7	10.69
10	540	4.5	5.5	10	540	4.2	6
11	560	4.8	5	11	560	4.8	2
12	575	5.3	3.5	12	575	5.3	2
13	585	5.8	3	13	585	5.8	1.5
14	592	6.5	2	14	592	6.5	1
15	600	7	1.5	15	600	7	0.5
16	610	7.6	1	16	615	8	0.2
17	620	8	0.5	17	630	10	0.2

The rates of growth, both in males and females, are about the same. Therefore the whitefish population in Lake Winnipeg will be as follows: $X_n=100\%\ C_n+100\%\ C_{n+1}+100\%\ C_{n+2}+98\%\ C_{n+3}+92\%\ C_{n+4}+72\%\ C_{n+5}+55\%\ C_{n+6}+39\%\ C_{n+7}+24\%\ C_{n+8}+13\%\ C_{n+9}+7.4\%\ C_{n+10}+5.4\%\ C_{n+11}+3.4\%\ C_{n+12}$.

(Average weight=3.04 pounds)

According to statistics the catches were as follows:

Year	Catches in pounds	Number of individuals	% of Cn.
1916	1,300,000	433,000	433,000
1917	2,815,000	937,000	937,000
1918	3,052,000	1,000,000	1,000,000
1919	2,975,000	990,000	970,200
1920	3,000,000 (?)	1,000,000	920,000
1921	3,143,000	1,000,000	720,000
1922	2,637,100	879,000	483,450
1923	1,626,400	562,000	219,180
1924	1,591,000	530,000	124,200
1925	2,559,000	853,000	114,300
1926	3,741,700	1,245,000	67,500
1927	2,826,000	942,000	50,870
1928	3,094,300	1,000,000	34,000

Therefore: The total number of whitefish in Lake Winnipeg in 1916, was 6,073,705. (Approximately.)

In Lake Winnipegosis: $X=100\%\ C16+100\%\ C17+100\%\ C18+95\%\ C19+35\%\ C20+61\%\ C21+45\%\ C22+35\%\ C23+28\%\ C24+22\%\ C25+16\frac{1}{2}\%\ C26+11.5\%\ C27+8\%\ C28$. (Average weight 3.122 pounds.)

Year	Catches in pounds	Number of individuals	% of Cn.
1916	288,000	96,000	96,000
1917	962,000	321,000	321,000
1918	1,000,000 (?)	333,000	333,000
1919	1,240,400	410,000	339,500
1920	700,000 (?)	233,000	198,000
1921	941,100	314,000	191,000
1922	722,200	240,700	109,320
1923	639,000	233,000	81,550
1924	690,000	230,300	64,500
1925	621,300	207,200	48,700
1926	833,700	277,900	45,850
1927	718,700	239,600	27,550
1928	674,500	224,800	18,000

Therefore: The total number of whitefish in Lake Winnipegosis in 1916 was 1,921,500.

Taking the same formula as for Lake Winnipegosis, we obtain for Lake Manitoba a total number of whitefish of about half a million (460,000).

(Average weight, 3 pounds)

Year	Catches in pounds	Number of individuals	% of Cn.
1916	112,000	37,300	37,300
1917	262,000	87,300	87,300
1918	200,000 (?)	86,600	86,600
1919	471,900	157,300	149,440
1920	100,000 (?)	33,300	28,200
1921	74,700	24,800	13,120
1922	77,600	25,500	11,480
1923	78,000	26,000	9,100
1924	99,000	33,000	7,920
1925	117,000	39,000	8,580
1926	136,500	43,500	6,960
1927	189,400	69,130	6,950
1928	179,800	59,600	4,210

Therefore: The total number of whitefish in Lake Manitoba in 1916 was 457,270.

All these amounts represent a minimum number of whitefish in the three largest lakes of the Prairie provinces.

Applying the same method of calculation for all five species of Lake Winnipeg tullibees we can estimate the total number of fish as about 100,000,000 with an average weight of each fish as 0.45 pounds.

The total number of many of our commercial fishes, especially those which have not very long duration of life and the accurate statistical material of which is available, can be estimated in most of our lakes. Only in that case, when the statistical material for a necessary number of years is unavailable is it impossible to make such a calculation.

If we know the total number of individuals of any commercial species of fish and know the average duration of life of this species, we can tell how much fish can be taken yearly from that body of water without the breaking of the balance.

The limit of catches can be formulated as follows:

$$L = \frac{P \cdot W}{D}$$

where: L—yearly limit in pounds; P—total number of fish in the lake; D—average duration of life; W—average weight of fish.

It seems to the author that this formula should be a foundation on which all fisheries could be based.

Certain other circumstances, as for example periodical increasings and decreasings (circles) in fish population and, connected with this, circles in our catches must be taken into consideration.

At the present time the average weight of many of our commercial fish in catches is, certainly, less than before. Twenty or even fifteen

years ago, twenty and twenty-five pound specimens of whitefish were not rare in the Prairie provinces. Now, the largest fish caught during the last six years was a female of sixteen pounds. We have no data concerning the average weight of our commercial and game fish twenty years ago, but, neglecting all the "fish-stories," it must be undoubtedly somewhat more than now.

In case of overfishing, decrease of the industry is accompanied by a decrease in the average weight of catches, but it would be wrong to connect a decrease of average weight with decreasing number of fish.

Together with a development of industry and the developing of fish culture we can observe a decrease of average weight in connection with a more rapid destruction and replacement, which makes the average life of fish very much shorter.

It seems more desirable from a practical point of view to have younger fish for sale than older ones, because the rates of growth and increasing of weight are going very much faster in young fish. After the fish reaches a certain age the increase in its weight becomes very insignificant, as old specimens consume food which is not turned into meat. Therefore from an economical standpoint it would be more advantageous if term D in our formula were only minimized to such a limit as to allow fish to spawn at least twice.

All the above considerations refer to the adult fishes which have already reached commercial size.

Let us now examine the second group, i. e., fishes less than commercial size. Studying the reasons of abnormally low production of young fish, we cannot always connect this phenomenon with poor spawning, but we must look for the cause in a great mortality of very young fry. It seems to the author that one of the causes of great mortality is lack of food, mainly plankton organisms. As a rule, the development of plankton, especially early in the spring, is periodical, and if these sudden developments of plankton do not take place until some time after the fry have hatched the result may be a very poor crop of fry, and after a certain number of years the catch of fish will be very poor. On the other hand, if there is a very plentiful crop of plankton at the right time, the catch, despite intensive fishing, may be very good. It seems to the author that this is a cause of puzzling periodical increase and decrease in catches.

The above considerations apply very well to the whitefish industry in the large lakes of western Canada. Therefore we must investigate every phase of development of whitefish, and especially those specific conditions under which the fry hatch and live. Artificial propagation and hatchery work cannot be based only on a large quantity of introduced fry but must be in accordance with those hydrological and hydrobiological conditions. In this way tens and hundreds of millions of fry would be kept from perishing. Only thus can hatchery work give good results.

Recently many investigators have found that the catches of adult fish continue to diminish in spite of increased introduction of fry, and as a result have criticized strongly the practice of fish-culture in general and have concluded that it is useless to build new hatcheries when we cannot see any results.

Although absolutely in disagreement with this opinion, the author, however, thinks that the hatchery work will be useful only in the event of all conditions being favorable for planting fry. The main thing in whitefish propagation in big lakes is to find the time and place for planting fry most favorably. Hatchery problems not only consist of artificial fertilization and hatching of fry, but also the protection of this fry from unfavorable natural conditions, otherwise the result will be only an increase of mortality of the fishes of the second group, i. e., fishes less than commercial size.

If we only imagine what a tremendous number of eggs are deposited by spawning fish we can understand how large should be those natural obstacles which every species will meet in the struggle for existence.

The following brief account of the number of spawn can illustrate this:

Salmo trutta fario	1,000	Clupea harengus	158,000
Salmo salar	25,000	Caspialosa caspia	148,000
Coregonus clupeaformis	35,000	C. caspia volgensis	179,000
Osmerus eperlanus	32,000	C. c. Kessleri	218,000
Leucichthys nipigon	30,000	Acipenser guldenstadti	234,800
Rutilus rutilus	84,000	Huso huso	1,380,000
Rutilus rutilus caspicus	56,000	Cyprinus carpio	1,000,000
Tinca tinca	70,000	Pleuronectes flesus	1,000,000
Lota lota	100,000	Gadus callarias	6,652,000
Esox lucius	136,000	Solea vulgaris	570,000
Abramis brama	150,000	Psetta maxima	10,000,000
Perca fluviatilis	200,000	Molva molva	28,361,000

If all the eggs deposited by fish should be hatched there would be no room for fish in all our rivers, lakes and oceans. There must be a great mortality among the eggs and fry. There may also be very imperfect fertilization under natural conditions in some species. We do not know very much about this. Only a few investigations have been made in this direction.

Downing (1910) estimates the number of eggs fertilized under natural conditions as not more than one per cent. He estimates that only 350 eggs are fertilized from a whitefish of average size and only 11 young fish will result from each pair of parents.

Professor E. E. Prince doubts that the percentage of fertilized eggs under natural conditions is so small and gives, among others, the following example, regarding sockeye salmon, in British Columbia. He gathered quantities of natural fish spawn in the beds and failed in some thousands of eggs, to get one single egg that was not fertilized, which showed how scrupulously nature accomplishes the

fertilization of eggs, under natural conditions. He says, that as far as his observations go, the eggs which were deposited by the parent fish are almost to an egg fertilized.

Mr. Fryer has collected salmon and trout and fertilized naturally, under normal conditions, and has not found 5% of the eggs unfertilized, so that, he says, there seems very great reason to doubt that the proportion of unfertilized eggs in the case of the whitefish can possibly be 99%, as suggested.

The observations of Capt. Lambson on the Sacramenta river on the natural fertilization of the salmon eggs, show that about 75% are fertilized under natural conditions, but further observations show that of the 75% which are naturally fertilized, fully 25% are smothered in the sand, so that eventually only a few hatch. Under artificial conditions from 90 to 95% were fertilized, and from 90 to 95% of the eggs fertilized, hatched and developed to fry.

We must remember that this observation was on trout and salmon eggs. Mr. Stranahan was instructed by U. S. Commissioner of Fisheries to make dredgings on the reefs with a steamer. He did so for several days, during the latter part of November and early in December. He had an inch hose and rotary pump and took up several thousand eggs. He cannot give the exact percentage, but it was somewhere in the vicinity of one egg out of 300 or 400, and as he remembers, he got only 11 or 12 impregnated eggs, during the two or three days' work.

Mr. Samuel F. Fulerton has been at it eighteen years, and has taken eggs off the bottom rocks and off the sand and brought them to the hatchery and hatched them, but he never got 1% of fry.

Our examination of whitefish eggs found in stomachs of whitefish in Lake Winnipegosis, 1928, shows that 85% were fertilized under natural conditions. About 30% of the fertilized eggs have been found in stomachs of whitefish from Atikameg Lake, Manitoba (1928).

In the fall of 1928, 1929 and 1930 we collected by means of a special dredge, which disturbs the bottom in front of a trap, several hundred of whitefish eggs from Lake Winnipegosis, and found that in some cases nearly all the eggs deposited under natural conditions were fertilized.

The author's opinion is that the percentage of fertilized eggs in the case of whitefish may fluctuate very considerably, reaching sometimes 90% and more, depending on spawning conditions, age of fish, fertility of males, temperature, dissolved gases, etc. Undoubtedly many fertilized eggs are subject to the attacks of many enemies and even of the parent fish themselves. On the other hand many millions of whitefish eggs are successfully hatched in our hatcheries and vigorous fry distributed. Some of our Prairie Lakes Hatcheries have successfully hatched from 70 to 90 millions of fry yearly and

operated for many years, but the whitefish population shows rather a decrease than increase!

Lake Winnipeg with an area of 9,460 square miles and Lake Winnipegosis with its area of only 2,086 square miles have both a hatchery with a capacity of 90,000,000 whitefish fry, respectively. Both of them have operated for a long time, but the author has found that in Lake Winnipegosis the relative number of adult fish is somewhat less (748 adult fish per square mile) than in Lake Winnipeg (933 adult fish per square mile).

We must also consider the comparatively small number of parent fish handled by the hatcheries, only 0.1% of all ripe females in Lake Winnipeg and 0.3% in Lake Winnipegosis, leaving 99.9% and 99.7% of all females to spawn in both of these lakes, respectively, under natural conditions.

If conditions are favorable there is no reason why fry should die. An exceptionally good example of such planting was the stocking of some lakes in Jasper National Park, with fry of speckled trout. Very large glacier lakes where was not a single fish before, became after four years the best fishing place in the whole North American continent.

Therefore, the main thing in the hatcheries is not to hatch successfully many million of fry, but to plant them successfully. Only skilled scientists can find how to protect them from perishing and how to change the tremendous supply of plankton and bottom organisms into fish meat.

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THE FERTILIZATION OF WATER IN EXPERIMENTAL PONDS

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There are two rather distinct objects in fertilization procedure that may be considered of prime importance from the fish cultural standpoint. The first is the production of animal plankton in fish rearing ponds—see Davis and Wiebe (1930) and Wiebe (1930)—and in natural waters where the fish must live, and, therefore, where there must be suitable conditions for them. The second is the production of animal plankton in the greatest amount possible, the removal of this plankton, and the feeding of it to young fish. We need pay no attention to the physical and other factors as they affect fish, but only insofar as they permit a good plankton growth. In our experiments we were concerned in the first place with the plankton productivity of ponds moderately fertilized, and, second, with following the biological and physical changes in ponds very heavily fertilized.

The process of fertilization with organic materials implies to a greater or less extent a pollution of the water, particularly in stagnant pools as were used in these studies. Therefore the two objects in experiment already mentioned need to be kept distinct, since, if fish are present, it becomes necessary to avoid excessive deoxygenation of the water, whereas certain planktonic animals, e. g., some pond entomostracans, can do with very little oxygen. The problem, therefore, is to determine how heavily the water can be fertilized economically and yet result in conditions compatible with fish life on the one hand and plankton growth on the other.

The experimental ponds in which these observations were made are situated on the hillside overlooking the St. Croix river at the Atlantic Biological Station, St. Andrews, N. B. All ponds, six in number, are well exposed. They are constructed entirely of concrete with the exception of one, which is lined with red brick (pond B2). The shape is either round or oval; the sides slope to a maximum depth of nearly two meters at the center. Their capacity is approximately thirty-five cubic meters. The water supply was that of the station, brought through iron pipes from Chamcook lake. The ponds are divided into two series, A and B. Two ponds of the A series were fertilized, pond A1, with 1,000 pounds of salt water mussels (*Mytilus edulis* Linnaeus) in the summer of 1927 and pond A2, with 1,000 pounds of fine cow manure in 1928. Pond A3 received the overflow from both of these ponds. In the B series experiments were carried out with smaller amounts of fertilizer. Pond B3 received one pound of herring meal (the entire fish is ground and dried), pond B2 twenty pounds of mussels, while pond B1 served as a control. The

meal was introduced at the beginning of each experiment in a coarse gunny sack and suspended at a depth of one-half a meter. The mussels were placed on a shelf of boards, also one-half a meter below the surface.

These ponds were planned by and constructed under the direction of Dr. A. G. Huntsman. They were constructed on a hillside to avoid any chance of flooding and to confine any interchange of water to precipitation and evaporation, unless otherwise desired. The primary purpose of the ponds was to elucidate the factors governing life in relatively stagnant water. To produce extreme conditions two of the ponds, as noted, were heavily fertilized. Observations were made upon these during 1927 and 1928 by Mr. W. S. Hall, and since the fall of 1929 by the writer. At the suggestion, also, of Dr. Huntsman experiments with much smaller proportions of organic materials were carried out by the writer for the purpose of determining the effectiveness of such limited fertilization as would alone be feasible for lakes, even where small.

In bodies of water, fertilized with organic materials, the supply and consumption of oxygen is affected by three principal factors, primarily, decomposition of the fertilizer always tends to deplete the supply. Secondly, the plant growth, which is a favorable result of the fertilization, produces oxygen by the process of photosynthesis and is the main agency in maintaining an abundance of this gas. Conversely, by their death and decay, plants also act as a depleting factor. Thirdly, the respiration of animals, as well as the decomposition of their dead bodies, consumes oxygen. Further, in an indirect fashion, the animals by consuming the plants aid the deoxygenation process. Any one of these factors rarely operates alone, but usually it is a combination of all these activities that determines the amount of oxygen in the water at any one time. However, the action of one factor, or one set of factors, may become dominant. The general result is a wide variation in the oxygen values.

Decomposition was rife in the two ponds most heavily treated (ponds A1 and A2) throughout the whole period that they were under observation. Such an amount of fertilizer primarily imparted a cloudiness and coloration to the water. The subsequent production of plant and animal plankton augmented the opaqueness. For instance, the greatest depth that a small modified Secchi's disc (a white crucible cover, 3.5 cm. in diameter) could ever be seen by the writer in pond A2 was 97 cm., and usually the depth was less than 50 cm. Readings as low as 10 cm. were recorded. The reduced light penetration and the resultant effect upon the temperature caused stagnation of the water over extended periods. This stagnation, coupled with the decomposition of the fertilizer, produced a deficiency of oxygen at the bottom, while the surface water, due to the photosynthetic activity of the plants, had often a supersaturation. Hall found on October 2, 1928, 16.2 c.c. of oxygen per liter

(16.0° C.) at the surface and 1.0 c.c. per liter at the bottom (13.0° C.). On August 6, 1930, we found the surface value to be 19.21 c.c. per liter (25.4° C.), and the bottom value 3.55 c.c. (16.5° C.). Again, on September 3 of the same year the oxygen content of the surface water was found to be 10.31 c.c. per liter (20.0° C.) and of the bottom 0.17 c.c. (15.5° C.). Such instances were common during these stagnation periods and only when circumstances permitted an overturn of the water were the values comparatively equalized from surface to bottom. (All determinations were made by the Winkler method and the sampling was done in the morning, except that by Hall, whose record was made at 4:00 p.m.).

Photosynthesis by the unicellular Algae was at times responsible for extremely high values in the surface water of pond A2. On April 11, 1930, the surprisingly high content of 25.05 c.c. per liter (10.0° C.) was found. In the same pond for the period from the above date until August 14 of the same year the lowest record was 13.35 c.c. per liter (9.9° C.) on May 28—a cloudy and rainy day with a fair breeze. Contents of 15-20 c.c. per liter were frequent. In fact a supersaturation was common in all the fertilized ponds as a result of the plant growth, and a measurement of this element served as a rough index of the abundance of these plants.

During September, 1930, there also occurred in pond A2 a very rapid production of two species of water fleas or cladocerans (*Daphnia magna* Straus and *D. pulex* [de Geer]). On September 3 in the surface water there were ninety-nine specimens of these two species per liter and 190 per liter at the half-meter level near the wall. By September 14 the number had increased tremendously and was mainly concentrated in the surface layers, where 6,115 individuals per liter were found. The reproductive capacity of *D. pulex* was notably high. Parthenogenetic females with as high as fifty-five eggs in the brood pouch were taken, and twenty to thirty-five was the general range of their number. The ultimate result of this heavy production was a marked reduction of the plant growth and, paralleling the increase of animals and decrease of plants, a diminution of the oxygen content. The value for the surface on September 4 was 4.01 c.c. per liter (17.6° C.). On September 17 this amount had fallen to 0.64 c.c. (18.45° C.) and the content remained low (3.5 c.c. and below) for the remainder of September and throughout October, increasing somewhat through November, but never rising above 5.5 c.c. as long as observations were made (December 8). At the same time the number of cladocerans declined to 1,147 per liter on October 9, but remained relatively high; as late as December 8, 343 specimens per liter were taken. This seems sufficient to show how heavy a growth of animal plankton was affected.

The inadequacy of diffusion to equalize the tension of oxygen as between successive layers of the water, or between water and air, was noted. It was found that a condition of either supersaturation

or deficiency would persist for some time in the immediate surface layer. It is true that the processes which were producing this condition were still active, but it is to be emphasized that there was no considerable entrance or escape of oxygen into and from the water. No doubt, other factors being constant, the surface waters would gradually reach a state of equilibrium with the air, but the process would be far too slow to materially aid any animals in the water which were dependant upon this phenomenon for their supply. This illustration may be enlightening. In 1929, some land-locked salmon fry escaped from experimental containers that were being held in pond A1. Two of these survived through the following winter and summer until early September. A period of stagnation occurred and all except the surface water become low in oxygen. A cool night lowered the surface temperature sufficiently to cause an overturn and consequent mixing of the water, and the oxygen in the surface layers was not enough to prevent the oxygen concentration throughout having very low values. As a result the fish succumbed. High temperature alone was not the responsible factor, since higher temperatures were recorded in June and July. The oxygen values at the time were 1.21 c.c. per liter (18.0° C.) and 0.88 c.c. (17.2° C.) at the immediate surface and bottom, respectively.

If we are primarily interested in merely producing animal plankton, it is not so essential to avoid intermittent depletion of oxygen. Certain plankton forms at least (*Daphnia magna, D. pulex, Scapholeberis mucronata* (O. F. Müller), *Heterocypris* sp. etc.) are able to withstand low concentrations. Thus a more intense fertilization is possible without jeopardizing the success of producing these forms in large quantities, to the exclusion, however, of susceptible animals.

It is becoming more and more the general opinion that the hydrogen ion concentration of the medium is not so limiting in its action as heretofore thought. Aquatic forms which were classified as living in habitats with a narrow range in hydrogen ion concentration (pH) have in many cases been found to tolerate surprisingly wide limits. However, in the concrete ponds which were fertilized, it is considered that the high alkaline values resulting from the large periodic growths of plants had a limiting action upon the number of species which could be propagated. Further, the relatively high values found in the unfertilized ponds as a result of the contact of the water with the concrete walls possibly acted in the same way. Klugh (1927) was not successful in growing plants and animals in small concrete containers. He attributed the failure to the high alkaline values of the water. Consequently, when the ponds were first constructed, an attempt was made to overcome the difficulty by paraffining the walls of one. Paraffin was applied and melted in with a blow torch. The attempt proved unsuccessful, however, as the alkalinity was kept low only for a few months, the paraffin gradually peeling away. Weathering was found more permanently effective.

In the experiments numerous species of pond forms of entomostracans were introduced, but the number of successful ones was relatively small. But, however limiting the high alkalinity may be toward certain species, others are quite able to tolerate this condition and to grow successfully in large numbers, as shown by the productivity of *Daphnia pudex*, etc.

When unaffected by plant or animal growth, or by decomposition, the pH values of the water in the ponds stood at 8.6 to 9.0. (A pH value of 7.0 is neutrality, i. e., the hydrogen ions and hydroxyl ions are present in equal concentration. Values below 7.0 signify an acid condition, above alkaline). The factors which operate to cause fluctuations in the oxygen content are also effective upon the hydrogen ion concentration. Decay of any kind and respiratory activity of animals and plants lower the pH by a liberation of the acid carbon dioxide, while photosynthesis causes an increase due to the consumption of this gas. Hall found that the values were about 9.8 during the summer season of 1928 in pond A1, and in the intensely fertilized ponds, we found pH values as great as 10.4. The lowest was 6.9 at the bottom of pond A2 during a period of stagnation (August 25, 1931). In pond B3, fertilized with one pound of herring meal, the values stood at about 10.2 from July 21 to August 25, 1931. This was at a time of maximum algal growth. In all ponds the prevalent values ranged from 8.0 to 10.0.

The experiments on the whole showed the efficacy of fertilizing the water in concrete ponds for increased plankton production, if we give due consideration to the limited number of species which occur. The addition of one pound of herring meal in pond B3 in 1930 produced about 100 times the amount of plants and about ten times the amount of animals found in the contol pond B1. Similarly, in the ponds more intensely fertilized, large numbers of plankton animals were periodically found.

A feature of both the plant and animal growth was the cyclic nature of the production. A notable instance of this was the *Daphnia pulex* growth in pond B3 during 1930. A maximum and minimum occurred roughly every three weeks. In other cases as well, it appears that forms found conditions suitable for their propagation, but at a certain point in their intensity of growth some factor or factors suddenly became unsuitable for their existence, annihilating some species and causing a decrease in the numbers of others. This complicates the problem of adequate utilization of the plankton. It would seem probable that when entomostracans, for example, were found to be on the increase, a partial removal would prolong the abundance. Although we can now say that by fertilization we can produce large quantities, we cannot always predict that a production will take place when most desired. This opens a field for fruitful research. Dealing with desired species and under more or less set conditions, can we not hope in the future to so perfect the procedure that a supply of entomostra-

cans will be at hand when required? In this connection, Langlois (1931) reports the inauguration of culturing *Daphnia magna* at Ohio hatcheries and evidently with some success. With the use of small containers in which physical factors can be adequately controlled and outside influences excluded, additional investigation should yield pertinent results.

As already stated, the number of species of entomostracans which occurred in the ponds was limited. This brings us face to face with a problem which is basic, that is the effects of the physical and biological factors upon the individual species. Why, for instance, were copepods present in such small numbers? Why did the cladoceran, *Ceriodaphia quadrangula* (O. F. Müller), occur abundantly in ponds A3 and B2, but in none of the other ponds although introduced? In the present state of our knowledge the ecological relationships of these animals is little known. It would, therefore, seem desirable to select a number of species which are of most value and have been found to be successful in fertilization experiments, and to study more exhaustively their reactions to the factors involved. This is not impossible. Certainly the results would be valuable and give an insight into what conditions to strive for and what to avoid.

The initial productivity in a fertilization procedure is that of the plants. Most of the microscopic free-floating algae are to be desired. Filamentous and large colonial forms are probably little utilized as food by the entomostracans and are, therefore, of doubtful value. Floating higher plants are decidedly detrimental. In 1931, a heavy growth of the duck weed *Lemna minor* covered pond A2 completely. This reduced the penetration of light to a minimal value and set up a state of decided stagnation. As a result there was an oxygen deficiency throughout the pond. The effects upon the plankton growth were disastrous. The microscopic algae practically disappeared and the animal life was greatly reduced. Although there was present a superabundance of nutrient salts for the plants (8,175 mgm. per m^3 of phosphate was found by Mr. John M. Morton in the surface water on September 5, 1931), lack of light permitted practically no growth. In turn the dearth of food, a prolonged deficiency of oxygen and of light, prevented a healthy growth of animal plankton from establishing itself. It is to be conceived, therefore, that any growth of the floating higher plants and, probably blanket algae, is to be avoided.

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THE PIKE OF WASKESIU LAKE, SASKATCHEWAN

A Preliminary Report

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INTRODUCTION

A study of the great northern pike *Esox lucius* has been one phase of the investigation of the game fish possibilities of the Prince Albert National Park. This investigation was begun by the writer in 1928 under the auspices of the Biological Board of Canada, which was forced to discontinue it in 1931. During 1931-32 a limited amount of financial support has been received from the University of Saskatchewan.

In 1927 the Prince Albert National Park was established in Northern Saskatchewan comprising some 2,000 sq. miles of lake and forest lands. Its popularity has increased rapidly until at present the annual visitors number about 3,000, many of whom are attracted by the fishing facilities. The pike of these cold northern waters are excellent for both sport and food and they constitute about 90% of the fish taken. Since most of these pike have been taken from Waskesiu lake, a body of water twenty-five sq. miles in area, it is not surprising that there has been a marked decrease in the number of fish caught during the last three years. The present study is therefore urgently needed as a basis for intelligent action in conserving this species.

We regard the spawning period not only as a critical one in the life history of the fish, but also as the time at which the fish population can be studied most effectively. In former years our university duties prevented our reaching the park so early, but in 1932 we arrived on May 12 and were able to observe the latter part of the spawning. We continued our examination of the fish which made up the spawning run until the middle of June. The results were so enlightening and of such significance in the conservation of the pike that it was considered desirable to make them known in this brief report.

SCOPE OF THE INVESTIGATION

The life history and rate of growth of the pike constituted the main problem and involved as well the determination of the time and place of spawning, the development of the eggs, feeding and growth of fry, the age at which the fish mature and spawn and the maximum age reached.

A second phase involved the pike population of the lake as to dis-

tribution, numbers, relative number and size of males and females, fluctuation in numbers and particularly the degree of depletion resulting from the heavy fishing carried on since 1928.

Accessory topics of importance were the food and feeding habits, and the external and internal parasites of the pike.

Much data have been collected in all of these fields but it should be understood that this report deals only with one phase of the investigation, namely, the study of the spawning run from May 12 to June 5, 1932.

Method of Attack

In addition to the careful observation of the pike under natural conditions, a source of information which nothing else could supplant, specimens were obtained from a variety of sources and submitted to a minute examination as to size, weight, body proportions, sex, microscopic examination of scales for age determination, examination of stomach contents for food data and the collection and identification of parasites. Such specimens were obtained from tourist catches, gill nets, seines and traps situated in streams and narrow channels. The latter methods provide additional data as to distribution and movements as well as a much more accurate sampling of the population than could be obtained from the random methods of angling.

For the spawning run it was necessary to place special traps in some of the important streams. The trap used in Mud creek may be described as typical of the three main traps used this spring. Diagram 1 indicates the nature of the trap placed in a part of the creek about eighty feet wide and two and one-half to four feet deep, with a relatively slow current.

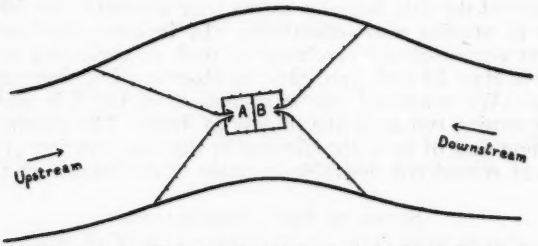


Diagram I.—Plan of the Trap used in Mud Creek

The fences were of fine mesh galvanized wire netting supported by stakes driven into the creek bottom. Special precautions were necessary to prevent the fish going under in the soft ooze and from leaping over the netting. (It was most interesting to see that even

a large (10 pound) pike could clear a barrier projecting ten inches out of the water in his efforts to get downstream. At least a dozen such leaps were observed in the period of observation). Fish coming upstream were directed by the long oblique leads into the trap A, about eight feet square. From this they were taken alive with a large dip net. Most of them were sent on upstream after their length had been measured and a small "V" cut from their dorsal fin. The remainder were killed and submitted to a careful examination, the results of which appear below. Similarly downstream fish caught in B were released below the trap with the anal fin marked, or were taken for examination as mentioned above.

Observations and Results

(a) *The Spawning Period*:

1. The spawning period began as early as May 1 (warden's observation) and continued until May 15, although the greater portion of spawning was over by May 12, when we began our study.

2. Spawning was later in the cooler water, e. g., in small bays off upper Waskesiu than in small muskeg lakes connected to Waskesiu by streams of various lengths. Spawning was observed in water of temperature 13° C. (55.4° F.).

3. Spawning grounds were found among the hummocks of sedges in protected weedy regions usually over a very soft muskeg. Ideal grounds were found in two small lakes—one near South bay and one at the extreme west end of the lake—connected to the main lake by narrow creeks 20-40 ft. wide and 100 yards long. A weedy bay off upper Waskesiu offered sufficient protection for spawning in the slow weedy parts of the creek, most of them in Mud lake some three-quarters of a mile upstream.

Eggs were taken and fertilized artificially at the spawning grounds but in the absence of proper retainers (jars) these eggs were killed by fungi (*Saprolegnia*) before they had completed their development.

(b) *Fry*:

1. The first fry were taken with the yolk sac not completely absorbed on May 25. The average length was 9 mm. This would suggest that the eggs took about fifteen days to develop and "hatch."

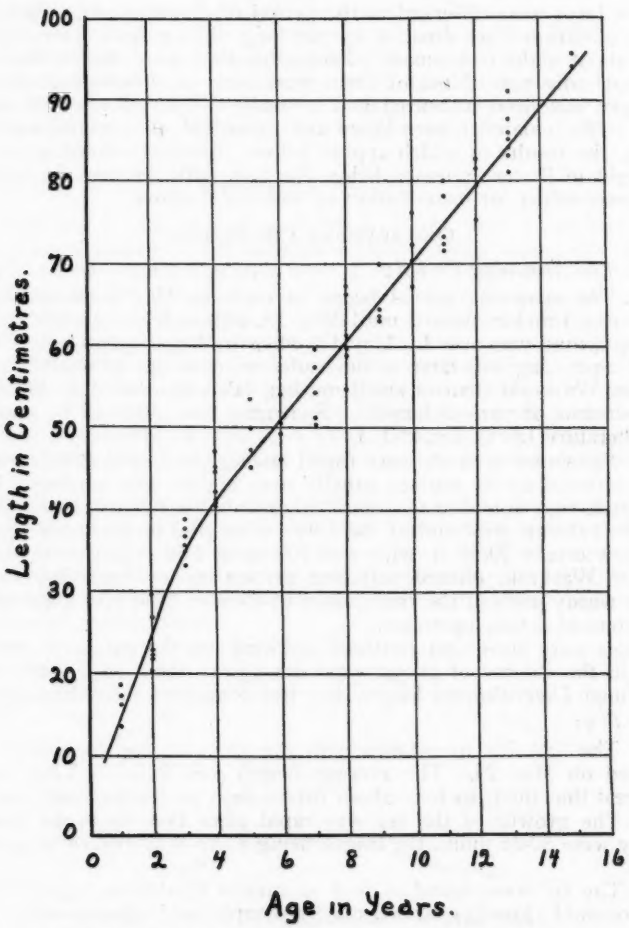
2. The growth of the fry was rapid after that time—on June 5 many were 30-35 mms., the length being more than tripled in sixteen days.

3. The fry were found to feed on minute Cladocera (water-fleas), Chironomid (junefly) larvae, mayfly nymphs and other insects.

(c) *Adults of the Spawning Run*:

A total of 324 adult fish were examined from traps in Mud creek, South Bay creek and West Bay creek.

1. The minimum spawning age: Some but not all of the female pike appear to spawn at the end of the third year, i. e., the third



Graph I.—Rate of Growth in Length of Waskesiu Pike

spring after the one in which they were produced. Few if any male fish mature until the end of the fourth year. In the following calculations the four-year group was taken at the first of the spawning run.

2. Distribution of age in the spawning run: The proportions of fish of various ages in the spawning run was as follows:

4th year	10.2%	10th year	5.1%
5th year	16.7%	11th year	6.5%
6th year	19.4%	12th year	5.1%
7th year	11.3%	13th year	3.4%
8th year	9.9%	14th year	2.0%
9th year	8.1%	15th year	1.0%

This distribution of ages in the spawning run is clearly shown in Graph 1. By plotting the lengths of all the 350 fish taken during and immediately after the spawning season it was found that each year class formed a fairly clear cut maximum in the distribution curve. It is to be expected that the lengths of fish in any year class would vary over a considerable range and thus overlap to some extent with those of adjacent years. Graph I indicates that this overlapping was not great enough to destroy the appearance of maximal numbers at the average length of each year class. These conclusions were verified by scale readings as may be seen in Graph II, which also indicates that the magnitude of variation in length in each year class was about 8 cms.

3. Distribution and variation of sexes in the spawning run:

The numbers of males and females were approximately equal in the spawning run.

The males were on the average much smaller than the females. No male was taken larger than 30.5 inches (70 cms. to the caudal peduncle), six pounds and ten years of age. Many females were taken between this size and the maximum of forty-one inches, seventeen pounds and sixteen years of age. A single 16-year-old female was taken in Mud creek.

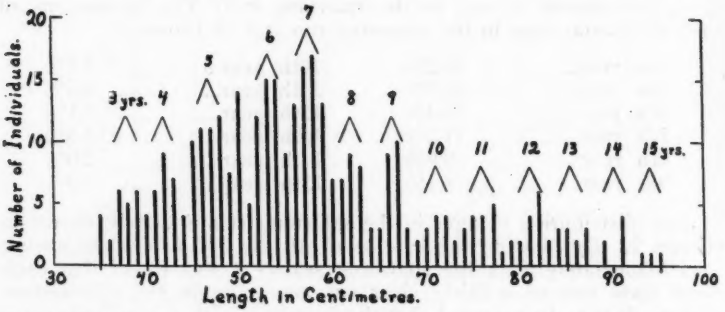
(d) *Rate of Growth*:

The determination of age by the scale method was satisfactory although in the older individuals the scales were somewhat difficult to read. Scales were read from a large number (95) fish and by examining several scales from each fish the growth curve indicated in Graph II was obtained.

1. The curve indicates a fairly rapid increase in length in the first four years after which growth is slower but uniform up to fifteen years.

2. In many of the scales from female fish a definite check was found between the circuli at the beginning of the fourth year's growth. This was not found in the scales of male fish and is be-

lieved to indicate the retarded growth at the first spawning period. It would thus verify the former observations that some female fish spawned at the end of the third year.



Graph II.—Distribution of length in 350 Pike from Waskesiu Lake showing year classes

The rate of growth in weight was also investigated and found to be quite unlike that of increase in length. During the first four years when length is increasing rapidly weight increases slowly. After the fish has reached sexual maturity increase in length is slower and it becomes steadily heavier for the balance of its life.

(e) *The Pike Population of the Lake*:

We hope in the future to make a comparison of the numbers and ages of pike which take part in the spawning run in a given stream on successive years. This would help us to estimate the condition of the pike population. The actual number of fish caught is none too reliable for this purpose because it varies with the intensity of fishing as well as with a density of the fish population. Moreover the full effects of depletion cannot be expected to show immediately in the number of fish caught.

The total catch would nevertheless be most valuable and in 1932 for the first time the gate-keeper at Meridion has been instructed to question all persons leaving the park as to the number and kind of fish caught and to record this information. This should provide a useful index to the fish production of the lakes and should indicate to what degree restocking and protection are necessary.

Application of Findings to the Conservation of the Pike

1. *The Fishing Season*:

The open season for pike in these lakes should begin not earlier than May 15th, spawning being practically complete by that time. The time of closing is unimportant as far as the pike are concerned, though in a group lakes where trout occur, the pike season should

probably close on September 15th, otherwise the spawning trout will inevitably be taken by those who are nominally fishing for pike.

2. *The Minimum Size of Fish to be Retained by Anglers*:

A common guiding principle in providing what might be called "normal" protection for a fish population is to set the legal limit so that every fish will be allowed to mature and to spawn at least twice. On this basis the minimum size of pike to be taken in Waskesiu lake would be 22 inches, length to fork of the tail. Such a fish would weigh about two and one-quarter pounds, which is comparatively small for these lakes. Few fishermen would care to keep a smaller one. This limit would protect about 25% of the spawning run.

If our methods of checking the population of pike should indicate a considerable depletion more stringent regulations could be applied as follows:

Proposed minimum length	Average weight corresponding	% of Pike protected for 2 years' spawning
22 ins.	2¼ lbs.	25%
24 ins.	2¾ lbs.	42%
26 ins.	3¼ lbs.	62%

A twenty-six-inch limit might be difficult to enforce but it would provide ample protection even with the most intensive fishing.

3. *The Effects of Overfishing*:

If, as we have good reason to suspect, the pike are being taken from Waskesiu lake faster than they can be replaced, protection should begin at once. Even a slight decrease in the number caught would indicate a serious condition because *the real effect of depletion will show only at five to seven years from the time of overfishing* since, as indicated above the major part (53%) of the spawning fish are of this age. In other words, it is the next generation of pike which will show the effect of present overfishing. Since the heavy fishing in Waskesiu lake began, about 1929, we would expect the resultant depletion to show clearly about 1935 to 1937.

Educating the Public in the Need for Conservation

After years of association with fishermen it is our belief that the majority of anglers are quite willing to follow the edicts of conservation if they can see the reason for and the advantages of such action. The following method is suggested as supplementary to and perhaps more effective than the usual pamphlet system.

Diagram 2 is the plan for a chart to be erected in a large frame at the entrance to the camp ground at Waskesiu Beach. (All visitors to the park enter here). The chart would be on a board at least 4 feet by 6 feet in size so that the various ages of fish might be illustrated life size and in their natural color. It is believed that this would provide a striking and interesting method of indicating the "whys" of pike conservation.

THE LIFE OF A PIKE.

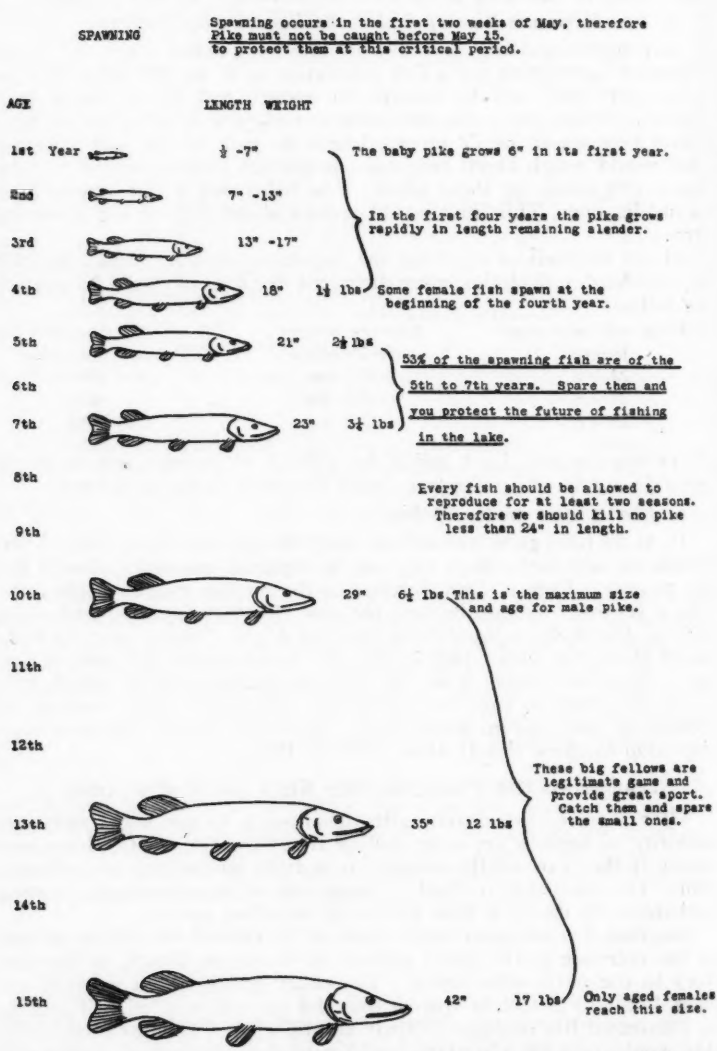

SPAWNING
Spawning occurs in the first two weeks of May, therefore Pike must not be caught before May 15. to protect them at this critical period.
AGE
LENGTH WEIGHT
1st Year
½ -7"
The baby pike grows 6" in its first year.
2nd
7" -13"
3rd
13" -17"
In the first four years the pike grows rapidly in length remaining slender.
4th
18"
1½ lbs
Some female fish spawn at the beginning of the fourth year.
5th
21"
2½ lbs
53% of the spawning fish are of the 5th to 7th years. Spare them and you protect the future of fishing in the lake.
6th
7th
23"
3½ lbs
8th
Every fish should be allowed to reproduce for at least two seasons. Therefore we should kill no pike less then 24" in length.
9th
10th
29"
6½ lbs
This is the maximum size and age for male pike.
11th
12th
13th
35"
12 lbs
These big fellows are legitimate game and provide great sport. Catch them and spare the small ones.
14th
15th
42"
17 lbs
Only aged females reach this size.

Diagram II.—Plan for a conservation chart to be erected in life size and natural colours

THE DEPTH DISTRIBUTION OF CERTAIN SPECIES OF FISH IN SOME OF THE LAKES OF NEW YORK

THEODORE T. ODELL*

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During the past four summers the author has had charge of the lake investigations carried on in connection with the biological survey being conducted by the New York State Conservation Department. During these periods (June 15-Sept. 15) collections of fish have been made in ninety lakes and larger ponds situated in the northern part of the state. These lakes ranged in size from Lake Champlain, 138 miles long, to ponds under half a mile in length. The majority of the lakes and ponds studied had an area of from 100 to 1,000 acres and a depth of 60 feet or less. The deepest water (400 feet) occurs in Lake Champlain.

The fish discussed in the following paper were all taken with gill nets whose bar measurements were ⅝", ¾", 1", 1½", 2", 2½", 2¾". These nets were simmed to stand six feet and were weighted to rest on the bottom. Each net was 100 feet long. The nets were set in gangs of four or five nets, the larger and smaller nets being alternated in most cases. Each gang was usually set in a given location for approximately twelve to sixteen hours over night. About a dozen day settings are included. A sounding was taken at each end of each gang and where necessary at the middle of the gang. The settings included in this paper are only those for which the soundings were such as to make it possible to place the fish caught into the arbitrary categories of depth which were selected. The percentages and graphs given below are based on 227 settings in which 5,348 fish were taken. These fish were all adults or juvenile specimens.

In arranging the tables and graphs no attempt was made to separate the settings which were made in lakes where a given species occurred from ones in lakes where it did not occur. This makes some difference in the percentages of fish taken at various depths; but it does not alter the shape of the curves. The species which were present in almost every lake studied were the common sucker, common bullhead, and common sunfish. Most of the lakes contained yellow perch and smallmouth bass. The other species occurred in less than one fourth of the lakes, the smelt being present in four lakes and the ling in two only. In a very few cases speckled trout were taken in lakes which contained yellow perch or smallmouth bass.

*The author is indebted to Professor Walter H. Durfee, of Hobart College, for help in working out the percentages and for making the graphs.

Of the species under discussion the smelt, cisco, whitefish, lake trout, fine-scaled sucker and burbot are classed as deep-water forms; the speckled trout, common bullhead, northern pike, smallmouth bass, common sunfish and rock bass are restricted to shallow water; and the remaining species, including the common sucker, yellow perch and pike-perch are most abundant in shallow water but range into the deepest portions of the lakes whose maximum depth is seventy-five feet or less.

The smelt (*O. Mordax*) was collected in Lake Champlain, the Saranac lakes and Schroon lake. Most of the specimens collected in water under 45 feet deep were taken in Lake Champlain in late June, although three of them came from Schroon lake in August in water less than twenty feet deep. In the case of Lake Champlain no smelt were caught in less than forty feet of water after the shallow areas became warm.

The 142 ciscoes (*L. artedi*) came from about a dozen lakes, the one specimen taken in shallow water coming from Hedges lake on June 26th, 1932.

The white fish (*C. clupeaformis*) was usually found in water over forty feet deep. In every case where the temperature was taken at a shallow-water setting in which this species was caught it was found that the bottom water was cold. Such shallow-water catches were made off the mouths of cold streams or at spring holes. The same hold true for the lake trout (*C. namaycush*).

The fine-scaled sucker (*C. catostomus*) is usually found in deep water during the summer months. But it ranges in the shallow areas if the temperatures are low. Most of the shallow-water catches were made in the vicinity of the mouths of cold streams or near springs.

All of the ling (*L. maculosa*) except one specimen came from Lake Champlain. This one specimen was taken in eighteen feet of water in Black lake. It was the only individual secured in the lake, although about twenty settings were made there. The maximum depth of this lake is twenty feet except in a small area of less than ten acres.

Although the speckled trout (*S. fontinalis*) is placed in the group of fishes confined to shallow water in lakes, it is always taken where the temperatures are low. During the four seasons not a specimen has been collected in a lake where the water was warm throughout. In shallow lakes where the water temperatures are high in general the speckled trout are found either off the mouths of cold brooks or in spring holes.

It seems unnecessary to discuss the other shallow-water species except to say that the common bullhead (*A. nebulosus*), northern pike (*E. lucius*), smallmouth bass (*M. dolomieu*), common sunfish (*E. gibbosus*) and rock bass (*A. rupestris*) were rarely taken in water

DEPTH DISTRIBUTION OF CERTAIN FISH
IN THE
LAKES OF NEW YORK
AS SHOWN BY GILLNET CATCHES
1929 - 1932
T. L. WELLS
Percent of Catch
Depth in Feet
Lake Trout
Smelt
Whitefish
Ciscoes
Yellow Perch
Sturgeon
Lake Herring
Blue Pike
Common Sucker
Pike Perch
Burbot
Common Eel
Rock Bass
Common Bullhead
Small-mouthed Bass
Large-mouthed Bass
Common Sunfish
Pumpkinseed
Black Bullhead
Brown Bullhead
Yellow Bullhead
Carp

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over fifteen feet deep. In this group the smallmouth bass is more definitely a fish of the shore areas than any other.

The common sucker (*C. commersonii*), yellow perch (*P. flavescens*) and pike-perch (*S. vitreum*) are more often taken over a wider depth range than any of the species mentioned above. They are not so definitely restricted to the extremely warm, shallow areas as are the members of the second group discussed. Neither do we find the majority of the specimens in deep cold water.

What factors influence the fish to bring about this summer distribution? We pass now from a consideration of data to a statement of convictions. It must be borne in mind that the collections were made at night, during the summer months, and that the nets fished only that part of the water which forms a covering over the bottom six feet deep. It is the author's belief that the principal factor in the distribution of the deep-water fishes and the speckled trout is the need for low temperature. It is taken for granted that oxygen relationships are satisfactory. Food in abundance and high temperature are probably the factors which restrict the shallow-water species to their habitat. The three remaining species, common sucker, pike-perch and yellow perch are evidently less restricted by temperature differences and are able therefore to forage over a wider range.

It will be noted (Table I) that 76% of the total catch came from water less than fifteen feet deep although only 60% of the nets were set in this depth area. The area next in depth contributed about 13% of the catch from 14% of the settings, while the water over thirty feet deep contributed only 11% of the catch, from 26% of the settings. It appears that the shallow water has a much denser population as compared with deep water than the last curve shows.

TABLE I

Species	No. of Col. in which species occurred	Total No. of Fish Col.	Number of fish collected at each depth										
			0′ to 15′	15′ to 30′	30′ to 45′	45′ to 60′	60′ to 75′	75′ to 90′	90′ to 105′	105′ to 120′	120′ to 135′	135′ to 150′	150′ to 165′
Smelt	12	79	0	19	13	25	19	0	2	1			
Cisco	9	142	1	0	39	95	7						
Whitefish	23	75	8	2	20	9	19	15	0	1	0	0	1
Lake Trout	17	37	6	1	8	14	8						
Speckled trout	43	117	84	31	2								
Com. sucker	137	1,640	1,348	238	51	3							
Fine-scaled sucker	28	124	19	56	16	28	5						
Com. bullhead	95	583	548	30	4	1							
No. pike	35	58	51	3	4								
Yellow perch	104	1,836	1,418	243	144	29	2						
Pike-perch	33	138	96	30	11	1							
Smallmouth bass	30	85	84	0	1								
Com. sunfish	66	356	328	28									
Rock bass	23	69	65	4									
Ling (burbot)	6	9	0	1	0	0	1	0	5	1	0	0	1
Totals		5,348	4,056	686	313	205	61	15	7	3	0	0	2
Per cent of total catch			75.8	12.8	5.8	3.8	1.1	0.28	0.13	0.06	0.0	0.0	0.04
Net settings	(total) 227		137	32	24	19	8	2	2	2	0	0	1

TABLE II

Species	Total No. Fish Col.	Number of fish per setting at each depth										
		0′ to 15′	15′ to 30′	30′ to 45′	45′ to 60′	60′ to 75′	75′ to 90′	90′ to 105′	105′ to 120′	120′ to 135′	135′ to 150′	150′ to 165′
Smelt	79	0.0	6.0	5.4	1.4	2.4	0.0	0.28	0.5			
Cisco	142	0.007	0.0	1.63	5.0	0.08						
Whitefish	75	0.06	0.06	0.83	0.47	2.38	7.5	0.0	0.5			
Lake trout	37	0.04	0.03	0.33	0.73	1.0						
Speckled trout	117	0.61	0.97	0.83								
Com. sucker	1,640	9.84	7.44	2.13	0.16							
Fine-scaled sucker	124	0.14	1.75	0.67	1.47	0.63						
Com. bullhead	583	4.0	0.94	0.17	0.05							
No. pike	58	0.37	0.09	0.17								
Yellow perch	1,836	10.35	7.59	6.0	1.52	1.52	0.25					
Pike-perch	138	0.7	0.94	0.46	0.05							
Smallmouth bass	85	0.61	0.0	0.04								
Com. sunfish	356	2.39	0.88									
Rock bass	69	0.47	0.13									
Ling (burbot)	9	0.0	0.03	0.0	0.0	0.13	0.0	2.5	0.5	0.0	0.0	1.0

TABLE III

Species	No. of Col. in which species occurred	No. of fish Col.	Percentage of catch per setting at each depth										
			0′ to 15′	15′ to 30′	30′ to 45′	45′ to 60′	60′ to 75′	75′ to 90′	90′ to 105′	105′ to 120′	120′ to 135′	135′ to 150′	150′ to 165′
Smelt	12	79	38.0	34.0	8.7	15.0	0.0	1.75	3.16				
Cisco	9	142	0.1	0.0	21.7	66.5	13.0						
Whitefish	23	75	0.47	0.47	6.48	3.67	18.5	58.5	0.0	3.9	0.0	0.0	7.81
Lake trout	17	37	1.9	1.4	15.5	34.2	46.9						
Speckled trout	43	117	25.3	40.2	34.4								
Com. sucker	137	1,640	50.2	38.0	10.9	0.8							
Fine-scaled sucker	28	124	3.0	37.6	14.4	31.5	13.5						
Com. bullhead	95	583	77.5	18.2	3.3	0.9							
No. pike	18	58	58.7	14.3	27.0								
Yellow perch	104	1,836	38.0	27.9	22.0	5.6	5.6	0.9					
Pike-perch	33	138	32.5	43.7	21.4	2.3							
Smallmouth bass	30	85	92.8	0.0	6.2	0.0							
Com. sunfish	66	356	73.2	26.9									
Rock bass	23	69	78.3	21.7									
Ling (burbot)	6	9	0.0	0.7	0.0	0.0	3.1	0.0	60.0	12.0	0.0	0.0	24.0
All species			29.6	26.8	12.6	10.8	8.1	7.7	2.5	1.5	0.0	0.0	2.0

Discussion

MR. TOWNER (Maryland): I have been very much interested in the rock bass on account of conditions at Deep Creek lake. I noted that in Canada they were putting a certain number of pike into their lakes to help to keep the rock bass down, so that the smallmouth bass would increase more rapidly. We have been putting pike into our waters for the same purpose. Are we working on the right lines?

MR. ODELL: Is that the northern pike, or pike-perch?

MR. TOWNER: Northern pike, I believe.

MR. ODELL: All three species, the rock bass, smallmouth and northern pike, have about the same range so far as depth is concerned in the lakes we covered. I do not know anything about the preference of the northern pike for rock bass or smallmouth bass, but from what I have seen of their feeding habits I should say they would take one as quickly as the other. I should hate to try the introduction of northern pike to protect some other fish.

MR. LECOMPTE: Mr. Towner has referred to the rock bass of Deep Creek lake. That is a lake twelve miles long and from half a mile to a mile in width, where the rock bass predominate, and they have very seriously affected the propagation of trout. In 1929 when this lake was first created, hundreds of thousands of brook trout fry were planted in it. This lake has the attributes of a splendid trout lake, but the rock bass, which were present in such large numbers, soon devoured the fry of the trout. Accordingly, in 1930, we adopted the system of planting what we call our jack pike or green pike, with small- and largemouth bass, hoping they would devour the rock bass. The rock bass constitute the majority of the fish caught there.

MR. ODELL: I have made some observations in connection with Indian lake, which is the oldest large reservoir in the State of New York, constructed in 1898. The fish present at that time, so far as we can tell, were northern pike (*Esox lucius*), minnows, perch and smallmouth bass. A few years ago rock bass gained entrance to the lake in some way; whitefish and lake trout had been stocked there. During this past summer we found that rock bass were very abundant in the lake, in spite of the fact that the lake is stocked every year with northern pike, and large numbers were taken from it every winter and quite a number during the summer. The whitefish and lake trout are getting along fairly well, and the smallmouth bass is a fairly common species and provides pretty good fishing.

MR. POWELL: The level of this lake fluctuates to the extent of 30 feet—it is up and down. You cannot get any plant or insect life to grow in it. With that fluctuation it is a problem to get something even to exist.

MR. LECOMPTE: Do you think the rock bass have increased over the last three years, or decreased?

MR. POWELL: This spring four men tried to catch enough rock bass to supply us, and in three days they got only about thirty pounds. They fished with eight or nine lines from four o'clock in the morning until late in the afternoon. We do not think, therefore, they are as thick as it is claimed.

MR. ODELL: Have you ever tried a fyke net to catch the rock bass?

MR. POWELL: Yes, but we could not get them that way.

THE IMPORTANCE AND CONDUCT OF HYDROGRAPHIC STUDIES IN LOUISIANA IN RELATION TO COMMERCIAL FISHERIES

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The marine problems of Louisiana are probably in many of their characteristics unique. This is due to the unusual and complex character of the waters of the Gulf of Mexico. Long ago, that brilliant American scientist, Matthew Maury, stated "The area of all the valleys which are drained by the rivers of Europe that empty into the Atlantic, of all the valleys that are drained by the rivers of Asia that empty into the Indian ocean, of all the valleys that are drained by the rivers of Africa and Europe that empty into the Mediterranean, does not cover an extent of territory as great or as fertile as that included in the valleys drained by the American rivers alone which discharge themselves into this our central sea (the Gulf of Mexico)."

If, for example, a single factor, the suspended materials borne seaward by the Mississippi river were considered, it will be found that within a single year this river is estimated to deliver into the Gulf of Mexico four hundred and six and one quarter million tons of silt. Figures perhaps best appreciated when it is realized that this astounding burden exceeds by seven and one-half times that yearly borne seaward by the Nile. It is obvious that this contribution, complex almost beyond belief, representing as it does the interaction of rainfall and stream flow with the immensely diversified structural components of the greater part of the North American continent, must profoundly alter and with its changing access variably affect the character of the shallow coastal waters of the Gulf of Mexico.

As is elsewhere pointed out, the Bureau of Research of the Department of Conservation of Louisiana has entered upon an extensive long-period investigation of commercial shrimp. Sea shrimp form the basis of one of the great fisheries of the United States which in 1930 totaled over 100,000,000 pounds and was eighth in volume and fifth in value of all United States fisheries. This investigation is carried out in a cooperative program with the Bureau of Fisheries of the federal government, to which program the states of Georgia and Texas also, though in a lesser measure, are contributing cooperation. The center of the shrimp industry lies in the Gulf of Mexico and the headquarters for this cooperative program are

located in New Orleans. The Bureau of Research of the Department of Conservation undertook, as one part in its share of the investigation, the collection and preparation of the hydrographic data in the coastal waters of Louisiana, the richest shrimp area now fished.

This paper is a brief statement of the purpose and conduct of the hydrographic work. The field work is being conducted by the use of a special research vessel of the United States government assigned exclusively to this work, the "Black Mallard," a boat 57 feet long with 14½foot beam and 4½ foot draft. As part of the cooperative program, the Department of Conservation has rebuilt this boat and has maintained her in operation. For the field program, Grand Isle has been made chief base because it is, in turn, the center of an unusually rich shrimp fishery. Located at the lower end of Barataria bay, Grand Isle lies in a typical Gulf coast setting of turbid shallow bayous and broad shallow bays. Anyone familiar with hydrographic work along, for example, the New England coast will be astonished at the profound contrast which the Louisiana coastal areas afford. An example, Barataria bay, may be given. This area of water, roughly about ten miles in length and about six miles in its greatest width, is in turn the center of an impressive network of lakes, bays and bayous that spread over some 400 square miles. This is relatively a vast area and yet if the channel that forms the pass between Barataria bay and the open Gulf of Mexico be excluded, nowhere in this maze of bays, lakes and bayous is there to be found a depth greater than seven feet.

The tides of the Gulf of Mexico are unusual and as yet are little understood. Instead of the double daily cycle as is characteristic of the Atlantic seaboard, there is in the Gulf of Mexico only a single daily rhythm with the addition, however, at certain widely separated points of a second cycle. A single daily high and daily low appear to be the rule along the Louisiana coast. The change in tidal levels is slight, with a mean range of tide of 1.3 feet at Grand Isle.

But superimposed on the tidal changes is the influence of wind exaggerated by the presence of broad areas of shallow water. As a result wind action may completely obliterate the normal tidal sequence.

Still to be considered is the influence of Gulf currents which likewise are not yet understood. There is a pronounced eastward current far out in the Gulf of Mexico, while between this current and the Louisiana coast there is a compensatory counter-current with a westward drift. These currents moving in contrary directions sometimes create spectacular tide rips and in the course of the shrimp investigations it has been possible to demonstrate again and again the juxtaposition of masses of water quite different in appearance, temperature and composition and yet so sharply delimited that if the vessel be placed transversely across the boundary, samples taken at one end of the boat will completely differ from samples taken at the other end.

It so happens that Louisiana's two most valuable marine resources —its oyster fishery which for the year 1931 amounted to a total of 1,425,000 bushels and the shrimp fishery which in 1931 showed for Louisiana a total catch of 37½ million pounds with a value of $1,314,000—involve animals in whose life history those stages of growth spent in the shallow coastal waters are of exceptional significance.

Some idea of the complex horizontal stratification often present may perhaps best be conveyed by citing an example. At a station off Southwest Pass (one of the mouths of the Mississippi river) June 15th, 1931, the surface water had a salinity of 9.6 parts per mille while at a depth of two and one-half meters the salinity was 33.4. Here cold fresh river water flows out over a warm gulf water of high salinity and the speed, the direction and the extent of their intermixture is determined by factors which are themselves highly variable.

In the course of this hydrographic work it became desirable to establish one offshore station at a position 135 miles out in the Gulf of Mexico where water temperatures and water chemistry were studied to depth of 1,200 feet. The salinity differences were within a narrow range, being 36.1 parts per mille surface and 35.3 parts per mille 400 meters down. The temperature range was considerable, being 25 degrees C. at surface and 11 degrees C. at 400 meters. The sea at this position has a depth of about 1,000 fathoms.

The hydrographic work now in progress falls into several categories. First, the systematic study samples taken at a series of carefully chosen stations representative of the range of conditions within the zone of the Louisiana coastal waters that is most significant for the fishing industry. These samples are taken in conjunction with biological sampling by shrimp trawl and by various types of plankton nets and thus their study is to be coordinated with the fauna present. All of these stations are occupied at intervals of about 2 weeks. The second, the conduct of a series of closely spaced observations through a complete tidal cycle at a single station. Such work is carried out at a series of stations representing a cross section of coastal conditions from the inside waters to the open gulf, the vessel moving directly from one station to the next at the completion of each twenty-four hour observation so that conditions under which these observations are made will be as similar as practical. Current meter determinations are also made throughout these periods. Third, the gathering of preliminary hydrographic data at various points of Louisiana coast extending from the waters across the border of the state of Mississippi on the east of Timablier bay on the west. Fourth, the conduct of extensive hydrographic studies in association with the studies of the currents and movements of larval stages of commercial shrimp.

This work, for its successful application to the life history prob-

lems, requires the carrying out of a program of investigation into the reactions of the larval and other stages of shrimp under experimental and laboratory conditions. This program is planned for the immediate future.

In the study of water conditions, the water samples have been collected with a standard Greene-Bigelow equipment, water temperatures have been determined by the use of Negretti-Zambra reversing thermometers, and salinities have been determined by the standard Mohr method, using an installation aboard the research vessel, which has been shown by constant checks ashore to be satisfactorily accurate. Hydrogen-ion concentrates have been ascertained by indirect methods. Turbidities have been estimated with a platinum wire apparatus.

It is not the intention of the present paper to present the detailed data of these investigations, since they will be appropriately published elsewhere. At present over 3,100 samples have been analyzed and it is hoped that as this work proceeds it will serve in time to fill some of the gaps in our knowledge of the extremely complex conditions of the Gulf of Mexico and adjacent inside waters and will further serve to provide practical information of fundamental value in understanding the distribution and welfare of such commercially important animals as the oysters and sea shrimp along the Louisiana coasts.

It is becoming progressively more and more clear that even the most hardheaded conduct of a commercial fishery requires for its continued success that it be conducted in proper adjustment to the sustained abundance of the animals fished. Such an adjustment in turn inevitably depends upon a knowledge of the life history, the movements and the reproduction of the commercial form, whatever its species. Physical factors such as salinity, turbidity and temperature exert the profoundest influence upon the commercial fishery. Such influences are, it should be repeated, of highest practical value and must be systematically measured and analyzed. Safe exploitation of the fishery resource is impossible if we do not possess these basic data.

SUMMARY OF EXPERIMENTS ON THE "ANABIOSIS" OF FISHES MADE IN 1931 AND 1932 AT WOODS HOLE OCEANOGRAPHIC INSTITUTION

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The problem of "Anabiosis" of fishes, i. e., of restoring them after apparently having been frozen to death, has been the subject of my experiments during the last two summers.

I am presenting a short summary of results attained so far, while the detailed report will be published later. One hundred and fifty-one experiments of freezing fishes and efforts to revive them were made. Of this number the positive and negative results were in the proportion of about fifty-fifty. Besides this, fifteen observations were made on the temperature of the body of fish during the process of freezing.

The following kinds of fishes were used in the experiments: killy fish (*Fundulus*), eels, gold-fish, young carp, hornpouts, perch and mud-minnows (*Umbra limi*).

The process of freezing was done in a Westinghouse household refrigerator by using its icemaking chambers. The temperature in this portion of the refrigerator could be lowered to —20 degrees C. By using the temperature control-device the temperature could be kept stationary at —15° C. to —10° C. The temperature was measured by a centigrade mercuroid thermometer with a precision of 0.1 of a degree and at the same time could be controlled by L. & N. Potentiometer-Indicator, which was located outside of the refrigerator. The precision of this apparatus is about one-quarter of a degree C. By using a subcutaneous thermo-couple needle, inserted into the body of the fish, its temperature during the process of freezing could be easily observed by means of the Potentiometer-Indicator.

A few experiments with larger fishes (eels) were performed in the icemaking plant of the Marine Biological Laboratory.

The results of the experiments can be summarized briefly as follows:

Freezing fish in air gave in all cases better results than freezing in water. In no experiment, in which fish were frozen in water, until the latter formed a block of ice with the fish inside of it, was there a recovery of the fish.

The period of exposure to a freezing temperature is of great importance. When frozen rapidly under a low temperature the fish recovered more readily than in those cases where freezing was prolonged under higher temperature. For example: Fish frozen in a quarter of an hour under a temperature of —14° C. to —15° C.

recovered in most cases, while those frozen during three-quarters of an hour or during one hour under a temperature of —10° C. to —12° C. did not revive. In most cases the temperature below —18° C. degrees centigrade was fatal for all fishes used in our experiments.

There is considerable variability in the resistance of different kinds of fishes under exposure to freezing temperature. Hornpouts (*Ameiurus nebulosus*) and *Fundulus* were found to be the hardiest in this respect; gold-fish and eels are weaker; young carp, mud-minnows and perch usually succumbed after being frozen.

The degree of freezing or amount of hardiness displayed by the fish after freezing is of great importance; apparently a fish can be frozen to death but in reality be only stiff. On the other hand, it can be frozen through, as hard as stone. In the first case the fish recovers rapidly and does not show any ill effects. When dissected it might bleed slightly, which indicates that the blood is not yet fully frozen.

In the second case the fish in most instances does not recover vitality. At least the experiments with the above mentioned fishes in most cases did not give positive results in fishes which were frozen stone-hard. If, however, it comes to life, it shows peculiar reactions; its body is curved and the fish cannot swim in a straight direction, but turns around, or moves irregularly. Its tail is often frozen to such an extent that in a short time a portion of it drops off, though the fish continues to live. Thus, there is a fatally low temperature for these fishes and when this is reached the fish cannot be restored to life.

Speaking generally, the temperature of —19° C. to —20° C. and the duration of one hour and more proved to be fatal in most of the experiments made with the named fishes.

Thus far I have made a few observations on the temperature of the fish-body as compared with the temperature of the surrounding air and can state some interesting facts about it, namely: the temperature of the fish-body when subjected to a very low temperature (—15° C.) drops very slowly. From plus 22° C. starting temperature it falls to minus 1.8° C. only after 45 minutes and does not go below this temperature.

A histological study of the tissues of frozen fish was made so far only roughly and inadequately. Observations have shown that in some cases, though the muscles, blood vessels and intestines are frozen hard, the heart may not be frozen through, and after being thawed out in tap-water, the blood circulation may be resumed, and the fish begin to breathe and swim.

In our experiments, a fish that has recovered, after being frozen, can live at least three to five weeks. On the other hand, only during a comparatively short period of time can a frozen fish be kept in an anabiotic state, i. e., in the state of temporarily suspended animation.

HYDROGRAPHIC BOTTLE FOR FISHERIES SURVEY

J. N. DWYER

Department of Colonization, Game and Fisheries, Quebec

A fisheries inspection of the inland waters of the Province of Quebec was commenced in the summer of 1930. The program was conducted by the Department of Colonization, Game and Fisheries to gather scientific data with respect to these waters and with the object of improving fishing conditions.

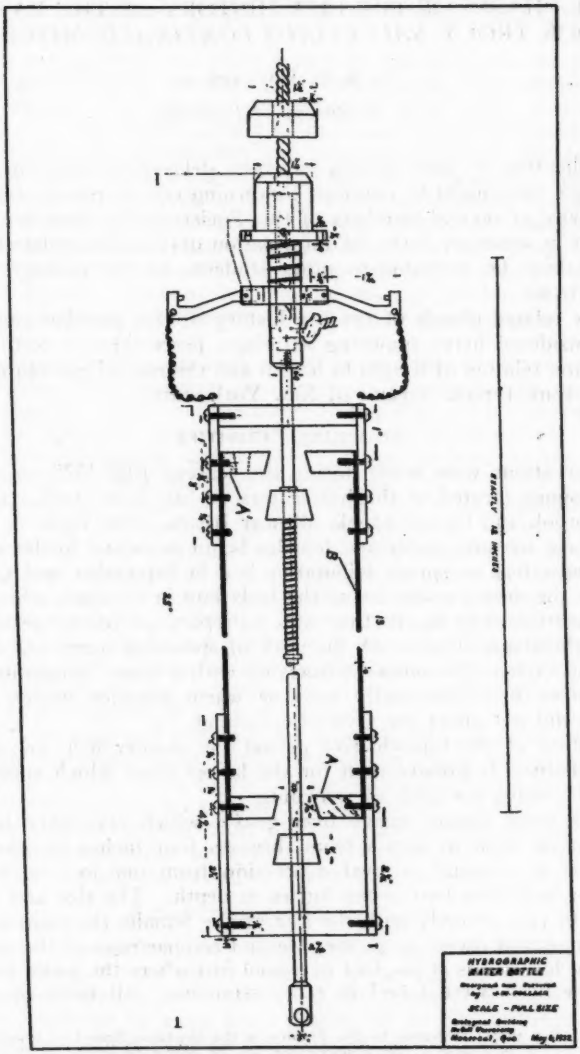
The question of obtaining temperatures below the water surface was one of the first problems which presented itself to the investigators. It was necessary to have a waterbottle for this purpose which was small and light in weight, and at the same time constructed so as to resist fairly hard usage.

The problem of obtaining a suitable instrument at no great cost was brought to the attention of Mr. Wallace Pollock, Technician of the Department of Zoology, McGill University, and resulted in the design and execution of a waterbottle, which to date has proven to be very satisfactory. The bottle has been used constantly in two summers' investigations and has been praised by those using it. It has a net weight of three and a half pounds and is simple in construction. The ends A and A', in the accompanying sketch, are of black celluloid; the body, B, is of transparent celluloid; the remaining parts are of machined brass. The body, as at present constructed, has a capacity of slightly more than one and a half pints.

The method of operation is not complicated: the instrument is lowered open into the water to the required depth and is closed by means of a messenger, which, by means of a spring in the neck of the bottle, releases the body on to the frustum-like pieces which act as stoppers in the ends.

The cost of the bottle in small quantities is $20.00.

A dimensional sketch and a photograph of the bottle are included herewith.



Hydrographic Bottle for Fisheries Survey

SOME PHASES OF THE LIFE HISTORY OF THE EASTERN BROOK TROUT, *SALVELINUS FONTINALIS* MITCHELL*

A. S. HAZZARD

U. S. Bureau of Fisheries

Publication of these results has been delayed in hope that more complete data might be obtained concerning certain phases, but upon the advice of several members of this Society it has been decided to present in summary form the information obtained in order that the results may be available to other students of the ecology of the brook trout.

Four related phases of the life history of this popular game fish are considered here: spawning activities, percentage of fertilization in nature, relation of weight to length and the rate of growth of wild fish in some typical streams of New York state.

SPAWNING ACTIVITIES

Observations were made during the seasons 1926-1928 on spawning grounds located at the headwaters of Six Mile creek, Harford Mills brook and Beaver brook, all near Ithaca, New York.

In these streams, males and females begin to ascend to the spring-fed headwaters or spring tributaries late in September and congregate in the deeper pools below the beds late in October, when both sexes are found on the nesting sites. Preparation of the nests is at its height about October 20, the peak of spawning occurring during the first week in November, associated with a water temperature of 49 degrees F. Abnormally cold or warm weather during these months did not affect the time of spawning.

Duration of the reproductive period for smaller fish, apparently newly mature, is greater than for the larger trout which appear on the beds during the peak of spawning.

Brook trout always spawn over gravel which may vary in size from coarse sand to stones from three to four inches in diameter. The nest is a round or oval depression from one to two feet in diameter and from two to ten inches in depth. The size and depth appear to vary directly with the size of the female, the swiftness of the current and inversely as the size and compactness of the gravel. Its usual location is at the foot of a pool just where the water breaks, but some nests were found in rapid stretches. All nests observed

*Based on a thesis presented to the Faculty of the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1931. The study was carried out under the direction of Prof. G. C. Embody, to whom the writer is indebted for sympathy and encouragement during its progress.

were either immediately below springs or in places where seepage entered through the gravel.

The female prepares the nest by darting upstream into the gravel, turning quickly upon her side and vibrating her body against the bottom, culminating with a sweeping action of the tail. Nest building was observed to last as long as two days. Observation at night with a gasoline lantern showed fish as active as during the day. A male was always seen in attendance whenever a female was found at work on a nest. He takes no part in nest building but is constantly fighting intruding males, relinquishing his position to stronger fish. One female was observed to have three successive attendants during the course of two hours. Twice during the three seasons' observation the female was seen to join the male in chasing intruders. Usually she remains indifferent to the competition going on among the males.

Courting activities consisted of two approaches by the male. In one of these he approached the female as she lay in the nest and pushed her gently from the center of the depression. A peculiar action by the male was also interpreted as courtship. He would swim above the female, first in back and then in front of her dorsal fin, touching her with his body and fins.

Spawning was presumed to occur when the male approached as in the first act of courtship and forced her upon her side at the bottom of the nest. A vigorous side-to-side vibration of both fish then occurred, during which it is supposed the eggs and milt were extruded, although sediment and motion of the water made it impossible to see them. Following this, the male dropped to the lower rim of the nest; the female immediately stirred up the gravel at the head of the nest as though covering the eggs. This spawning act, which lasted about two seconds, was repeated during one observation after an interval of about ten minutes.

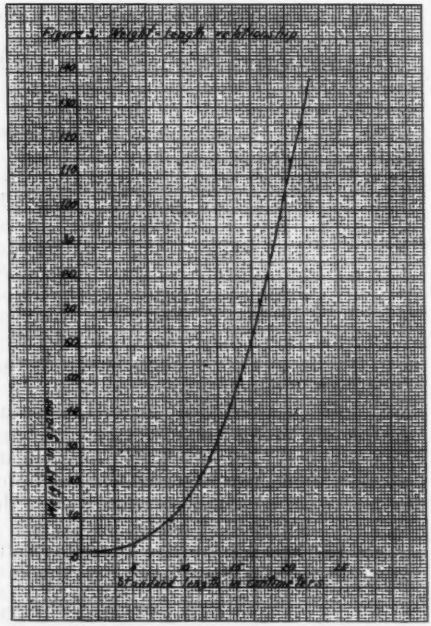
After spawning and covering the eggs, the female apparently deserts the nest, but the male may remain on guard for as long as two weeks. In two nests which had been watched during the season, the males were examined a week after the females had left and were found to contain a little milt. When released they darted downstream but had returned to their respective nests within ten minutes. Eggs taken from these nests two weeks later were well eyed.

Percentage of Fertilization

Since trout have been propagated artificially, it has been the fond belief of many fish culturists that the percentage of eggs fertilized under natural conditions is very low. To throw some light on this question, samples of eggs from twenty-six to 636, averaging 201 each, were taken from twenty-one different nests in the three streams studied. The locations of the nests were marked during the spawning period and the eggs removed with the aid of shovel and screen

after sufficient time had elapsed for the eyed stage to appear. This precaution is necessary in order to distinguish between eggs killed in digging and those which have not been fertilized. The percentage of eggs containing embryos varied from 27 to 98.5, with an average of 79.8, all but one nest showing better than 69% of the sample to be alive. White (1930) records a hatch of 79% from a nest of a brook trout which he dug immediately after spawning had been completed.

When it is considered that the eastern brook trout is a nest building fish, the female producing relatively few eggs, biologists would expect the percentage of fertilization to be high, particularly since the fry are exposed to so many dangers once they have emerged from the gravel. It is the care of the fish during the critical stage of its existence which is the fish culturists' greatest contribution to the stock in our streams.



Graph Showing the Weight-Length Relationship

Weight-Length Relationship

Relation of weight to length was studied from collections made in eighteen streams of New York state. The fish, 382 in number, ranged from 3.9 to 23.5 centimeters standard length and were taken over a period of several years, the majority from April to August, 1930 and 1931. Data from a few lake and hatchery trout are also presented for comparison.

The formula proposed by Hecht (1916) was used in the calculations. This formula is as follows:

$$a \text{ (the condition factor)} = \frac{100 \times \text{weight in grams}}{(\text{standard length in centimeters})^3}$$

The average for stream trout was found to be 1.367, being slightly higher than the mean up to fifteen centimeters and lower than the

mean above this size. Individual variation is illustrated by a catch of forty-one trout from Zina brook in which the condition factor ranged from 1.181 to 1.754. The average for each of eighteen typical streams varied between 1.235 and 1.473.

Seasonal fluctuation in the condition factor undoubtedly occurs, the fish being heaviest at the spawning season, losing weight thereafter and not recovering condition until after several weeks of feeding in the spring. The average for fifteen specimens from Harford Mills brook taken April 17, 1930, was 1.223. Thirteen fish from the same stream taken May 22, 1930, averaged 1.347. Further study of the seasonal fluctuation in the weight-length relationship in the brook trout is to be desired.

Data available for trout of lakes and for hatchery fish indicate that their condition factor is much higher than that of wild stream fish. Fifteen specimens from Mud lake, Quebec, gave an average of 1.756. Thirty-seven trout from a central New York hatchery averaged 1.555.

In his studies of the California sardine, Clark (1928) determined that variation in the fat content of the body tissues is responsible for the variation in the condition factor. This appears to be true for the eastern brook trout, although chemical tests were not made. Variation in the fat content is believed to depend upon the type and abundance of the available food and the energy required to secure it and combat the current.

Rate of Growth

Scales of 202 trout 3.9 to 23.5 centimeters standard length (1¾ to 10¼ inches total length) from thirteen typical New York streams and from a few lake and hatchery fish were cleaned, mounted in glycerine gelatine and studied with microscope and projection machine. Though minute and difficult to prepare and study, it is believed that the scales of this species are usable in determining the rate of growth under most conditions. Kendall and Dence (1927 and 1929) have made use of the scale method in determining the age classes of trout in several streams of New York.

The annulus or year mark is apparently formed in winter when growth is retarded and is indicated on the scales by a crowding and incompletion of the ridges (Figs. 4-13). Marked variation in the definition of the annulus is found in trout of different streams, being most distinct where considerable seasonal temperature fluctuation occurs. In the majority of scales, the first few ridges laid down following winter retardation are unusually distinct and frequently extend into the posterior field of the scale (Fig. 8).

By projecting the enlarged image of the scale, measurements of the anterior fields were made and the length of the fish at each annulus calculated by the formula given by Johnston (1905). Since scales do not appear in the brook trout until a length of approxi-

mately 4.0 centimeters is attained, the correction to Johnston's formula as proposed by Fraser (1916) was used. The formula reads:

$$\text{Length at annulus} = \text{the unscaled length (4.0 cm.) plus } \frac{\text{length of anterior field at annulus}}{\text{length of anterior field of entire scale}} \times \text{length of fish at death minus the unscaled length.}$$

This formula merely expresses the fact that the growth of the scale is in proportion to the growth of the fish in length making due allowance for the unscaled length of the fish. The calculated average lengths determined from the use of this formula were found to be consistent with the actual average lengths of the year classes.

Marked variation in growth rate was exhibited by trout of different streams. Fish from small, cold headwater streams of the Adirondacks showed much slower growth than fish in lowland streams where fish are fewer, summer temperatures higher and the growing season longer. Examples of this variation are shown by the following table:

Stream	Number of individuals	Length at 1st annulus	Length at 2nd annulus	Length at 3d annulus
Middle Kiln	12	7.6 cm.	9.0 cm.	11.8 cm.
Fish Creek	42	7.7	12.5	17.4
Zina Brook	41	8.2	11.6	17.0
Willow Bridge	19	10.5	15.9	—
Average for 13 streams	202	9.4	13.5	16.8

The striking growth (9.4 centimeters standard length, approximately 4¼ inches total length) made by the average wild trout during its first year of life is accounted for by the equable temperature of the spring feeders in which the first year class is usually found. In streams, such as Willow Bridge, which are heavily stocked and fished, this growth may be due in part to the large sized fingerlings liberated here by the state, but undoubtedly warmer water and longer growing season are the principal factors.

The great majority of legal trout in the more heavily fished streams were found to be in the third and fourth years of life. Individuals older than this were too rare to be used in this study. The present legal size (6 inches) protects the eastern brook trout barely through the second year of life in the better streams of the state. Since trout do not spawn for the first time until the end of the second year and then the females produce few eggs, it can be appreciated that little opportunity is afforded for much natural reproduction. However, in cold mountain streams such as Middle Kiln, the six-inch limit protects many fish even in the fourth year of life and aggravates the overstocked condition of these waters. The data collected by the biological survey now in progress in New York could be used to advantage in establishing more suitable size limits for the principal streams of the state.

Figure 4
Figure 5
Figure 6
Figure 7
Figure 8
Figure 9
Figure 10
Figure 11
Figure 12
Figure 13

Fig. 4. Scale of trout in first year of life, 4.2 centimeters, from Zina Brook, August 3, 1930. Enlarged 35 diameters.

Fig. 5. Scale of trout in second year of life, 8.8 centimeters, from Fish Creek, June 29, 1927. Enlarged 35 diameters.

Fig. 6. Scale of trout in third year of life, 14.4 centimeters, from Lower Harford Mills Brook, May 5, 1930. Note second annulus is close to the margin of the scale. Enlarged 35 diameters.

Fig. 7. Scale of trout in fifth year of life. Rapid growth in the last three years is presumed to have taken place in reservoir below stream where fish was taken. From trout 26.6 centimeters long taken in the Salmon River, June 24, 1928. Enlarged 35 diameters.

Fig. 8. Scale of trout in sixth year of life illustrating lake growth. From fish 42 centimeters in length taken in Roiley Pond, September 5, 1930. Enlarged 35 diameters.

Fig. 9. Probable rapid growth in spring-fed, watercress stream. Scales are unreliable due to equable temperature. From trout presumed to be in its second year, 21.0 centimeters long, taken in Thornell Brook, May 5, 1930. Enlarged 35 diameters.

Fig. 10. Rapid growth in a selected strain of hatchery trout. From fish 32.5 centimeters known to be in its second year, killed November 18, 1930. Enlarged 24 diameters.

Fig. 11. Slow growth in a cold mountain stream. From a trout in its fourth year of life, 14.0 centimeters, taken in Middle Kiln Brook, August 14, 1930.

Fig. 12. Regenerated scale, lost and replaced near end of third year, a common feature in the brook trout. From a fish 26.9 centimeters, in fourth year of life, Salmon River, June 24, 1930. Enlarged 35 diameters.

Fig. 13. Twin scales caused by fusion of scale pockets. From fish 19.1 centimeters, Salmon River, August 24, 1930. Enlarged 35 diameters.

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THE AMERICAN FISHERIES SOCIETY AND THE FISHERIES

HENRY O'MALLEY

Commissioner, U. S. Bureau of Fisheries

For the past several years circumstances of time and place have prevented my attendance at the annual meeting of this organization. I am, therefore, particularly gratified that I have been able to arrange affairs so that I can be here this year and explain to you in person that my absence heretofore has not been due to lack of interest in the organization or lack of conviction that the meetings are well worth the time spent on them. Both personally and officially, I am very much pleased to be with you.

While we in Washington are not the hosts to the convention, our role as near neighbors to Baltimore seems to warrant our extension of an additional welcome to those who are visiting this section from such diverse and far distant points.

I know you will enjoy your stay in Baltimore and the beautiful State of Maryland where true southern hospitality will be given you by the Maryland State Conservation Commission and its able officials, Commissioner Swepson Earle and Game Warden E. Lee LeCompte.

I intend to make only the most casual references to fish in the course of these remarks, preferring to speak more exhaustively on the subject of fish culturists. The purpose of this convention is to afford all parties who have, or feel that they have, the "low down" on fish an opportunity to get their information out of their system. I have no doubt that in the meetings and discussions to follow, the most sacred and inmost facts concerning the weaknesses, follies and virtues of any and all fish will be dragged into the light of pitiless publicity. We would all dislike to have comparative data concerning ourselves brought out and discussed with the same frankness. In fact, it has sometimes occurred to me that the carmine tint of the goldfish is simply a perpetual blush induced by the ruthless lack of privacy in the most personal relationships of which the goldfish has been the victim for untold generations.

In spite of the tremendous problems which have pressed upon the country during the past nine months, the fish culturist and his activities have received a back-handed recognition, which may or may not be gratifying. I refer to the fact that the Federal Economy Bill, spawned in the turmoil of billion-dollar reconstruction projects, budget balancing, etc., carried as one of its items, to start with at least, a proposal that federal fish hatcheries be turned over to such states as would request them. I have no hesitation in uttering certain

thoughts which occur to me in this connection. In the first place if any struggling state took over one of the federal fish hatcheries, I am of the opinion that it would only work to the detriment of the state and eventually slow up the production of fish for various sections of the country.

From meager information I have received, I feel that most of the states would not approve of such action, but would prefer that the United States Bureau of Fisheries operate and co-operate with the various state organizations within the boundaries of the several states. I do not believe that the hatcheries could be conducted more economically by the states and such a transfer would simply signify the shifting of the cost of operation from the federal taxpayer to the state taxpayer and it is a well-known fact that the bulk of the taxation is of a state and local nature. The federal hatcheries are an insignificant item in the federal budget, but would loom rather large in the expenditures of state fish and game departments which are struggling to keep their heads above water in the face of curtailed income. I do not believe any one will assert that there is an excess of hatchery fish production at the present time, and if any state should be so fortunately situated as to be able to take on added obligations, it would appear to be the part of wisdom to establish new or enlarged state hatcheries as a supplement to the federal hatcheries. If a hatchery is transferred from the roster of the federal government to that of a state, there would be no larger quantity of fish available to meet the pressing needs. However, nothing more need be said about the matter at the present time since the proposal seems to be temporarily quiescent.

After a superficial investigation, I feel that the various conservation departments throughout the United States have been more or less crippled through the stress of necessary economies, but I hope that the economic plight in which we all find ourselves is not going to cut so deeply into the future conservation program as to wreck and destroy the splendid conservation work which so many of the states have been carrying on. The arteries of financial support have been seriously constricted, but I believe that the splendid fisheries organization in Michigan, for instance, is still doing an excellent work in an efficient manner, even though its funds have been slashed. No one will fear but what Michigan and dozens of other states will be back on the job as formerly as soon as the financial pressure is reduced. There have been some gains, while the country as a whole has been hunting for the storm cellar.

Everyone familiar with the situation and interested in fisheries conservation cannot but be pleased to see what has been accomplished in Mississippi in the way of setting up an organization to control fish and game matters in a scientific and efficient manner, rather than by haphazard and spasmodic efforts. Commissioner Stobie, in Maine, has been proceeding along his serene and un-

troubled course during the entire period of the depression, and I am convinced that the Pine Tree State is far ahead of its position of three or four years ago so far as fisheries protection, propagation and conservation are concerned. In singling out these states, I have merely cited examples which have come to mind and intend no invidious comparisons with other states.

As far as the Bureau of Fisheries is concerned, our fish cultural work and aquicultural activities have been trimmed to the point where they resemble the Thanksgiving turkey at the close of that festive day. There is still considerable meat left on the bones, however, and I believe that from that sufficient can be salvaged to make our efforts of continuing value. Something over 20% has been the reduction in our appropriation for hatchery work, and we are thrown back to the status of several years ago, prior to the initiation of the five-year building program and before we had the additional facilities and responsibilities in the way of new hatcheries which were the outcome of that project. Belts must be tightened up somewhat and it is possible that two or three extra holes will have to be punched in order to fully meet the shrinkage; but I am confident that the Bureau of Fisheries still is, and will continue to be, an important factor in the conservation work in the United States.

At the present time we are concentrating more and more upon experimental work with the intent of developing information which will render our own activities more efficient and will be available for the states in case they care to adopt it with like purpose. Our efforts in this field include three experimental hatcheries, operated primarily for the purpose of developing the basic data concerning this problem in applied biology, the artificial propagation of trout and bass. In addition, investigators are detailed to several other hatcheries to study problems of pathology, feeding, etc., and really to act as trouble shooters in meeting the difficulties which no hatchery escapes.

The Bureau has also furnished a man to take charge of an unique experiment in community fish rearing at Rochester, N. Y. The public parks in the vicinity of that city afford unusual opportunity for the propagation of pond fish, and there has been developed in cooperation with the New York Conservation Department, city authorities, and the Izaak Walton League, a plan to use this area as a laboratory for demonstrating how communities can be self-sufficient in producing fish for their own territory. We are all aware of the accomplishments of the city of Tulsa, Oklahoma, in this respect. It seems a decidedly worth-while endeavor to popularize the plan wherever possible and to formulate necessary plans of procedure which will be applicable on a wide-spread basis. Our strictly experimental work, carried on under Dr. Davis, has to do with selective breeding, nutrition, etc.

In this connection we encounter problems akin to that of the young wife who bought a highly advertised tonic guaranteed to produce

health and vigor in babies. Shortly thereafter she returned to inquire shyly of the druggist if he was certain that it made healthy strong babies. Being assured on that point she asked "Who takes it? My husband or me?" I have concluded that a tonic which could be administered to fish culturists to make them more alive to the possibilities and problems of their calling might possibly result in gratifying improvements in the quality of the fish produced. Not all fish culturists are in need of such a stimulant, but too many of them are, and at the present time the American Fisheries Society appears to be the only tonic which can be supplied to those individuals who are suffering from atrophy of the gland of progress.

The American Fisheries Society is an unique organization from several standpoints. There are organizations of scientists and practical men in many fields. During temporary absence of the doorkeeper, I have managed to crash the gate at meetings of the former class and have found the intellectual atmosphere as thick and noticeable as the atmosphere surrounding a 10-cent perfume counter. I have also attended meetings of the practical men in fisheries fields where the mention of science or scientists would bring a reaction similar to that which accompanied the mention of prohibition in our recent political conventions.

The American Fisheries Society, however, offers a forum, or possibly I should say arena, where representatives of both groups can meet, exchange ideas, and sometimes take it on the chin if their conclusions or facts are not straight. This results in a mutual respect on the part of each. I believe that when Charlie Hayford and Dr. Embody or Dr. Davis and Glen Leach encounter each other and thresh out some debatable point, the experience is beneficial to the participants on both sides and it is certainly enjoyable to the spectators on the outside. In too many laboratories and research centers, scientific investigators are digging out important facts and immediately interring them where they may never see the light of day again and are lost to all possibility of practical application.

The American Fisheries Society is an agency which prevents such a situation in the field of fisheries conservation. Like Old Man River, the Association "justs keeps on rollin' along." An organization which has thrived for a period covering three generations, has withstood wars, economic depressions, and all other disasters which beset human institutions, is not in need of any eulogy from those who happen to constitute its membership for a short period through its lengthy career. It is even unnecessary to assume the risky role of prophet and foretell future progress and success in its efforts. Such a future is a foregone conclusion with an organization of the character of the American Fisheries Society. The institution itself is bigger than its members, individually or collectively, in spite of those capable and prominent individuals who belong now or have belonged in the past.

DEVELOPMENTS IN THE CLEAN STREAMS CAMPAIGN

S. B. Locke

Conservation Director, Izaak Walton League of America

The Izaak Walton League has continued its efforts to arouse the "great American public" to demand its rightful heritage of pure water since the President's Conference on Outdoor Recreation, in 1927, invited it to undertake a nationwide campaign for clean streams. This program was materially advanced by the counsel and advice of Dr. Henry Baldwin Ward, an outstanding authority on pollution problems and a past president of the American Fisheries Society. During the past year, sentiment has been stimulated as never before and activity throughout the country convinces us that the program for clean streams is progressing.

It has long been a fond hope that some Croesus, imbued with an altruistic spirit, might become sufficiently enthusiastic over the picture of possibilities presented in a clean streams campaign for an everlasting monument to subsidize a staff of field experts, chemists, engineers, lecturers, etc., who could devote all their time to militantly promoting the program. Pending the availability of such benevolence, we are carrying along the work, depending a great deal for assistance on the cooperation of state health departments, sanitary engineering firms, trade associations, conservation officials and our local chapters.

We want our rivers and streams back in their natural pristine beauty, and we want fish in them to make them complete. Fish lend charm and life to our streams and lakes, and their presence encourages even the mightiest among men to seek recreation and solitude along sheltered shores. But we cannot base our campaign for clean streams on the loss or absence of fish alone. The fisherman mourns the loss of his favorite trout stream or bass pool, but chances are he will not take the loss as philosophically as he does a day without a strike. He will raise a hue and cry because his sport is ruined, but unless other values are affected he will arouse little sympathy. The public health worker, the sanitary engineer, the biologist, all appreciate other values. So let our campaign include not merely "pollution" with a resultant loss of fish, but rather present the problem to the public as the conservation of water resources vital to existence, including the health, economic and esthetic phases.

National Pollution Problems

The Capital City presents a disgraceful example of stream defilement. The historic Potomac, now an open sewer, threatens the

health and well being of its residents and visitors; it is unfit for recreation uses; it is death to fish and waterfowl which formerly found haven there. But this desecration must not be allowed to continue. Action of the last Congress declaring the District of Columbia a migratory bird refuge, spurs the lovers of wildlife to action. Sportsmen's organizations, particularly the American Game Association and the Maryland-District of Columbia Council of the League, are protesting in loud voice. The battle is on to clean the Potomac.

Then there is the Mississippi river flowing through the luxuriant valley which it has created, carrying its over-load of pollution from its early reaches and gathering more wastes as it progresses southward. The most notorious offenders of the upper river are the Twin Cities, St. Paul and Minneapolis. Here the river receives raw sewage from about 1,200 miles of sewers and a naturally beautiful portion of the Mississippi becomes a public health menace and is ruined for recreation. The construction of dams with the resultant deposition of silt intensifies the damage from pollution. The welfare of the Upper Mississippi Wildlife and Fish Refuge is threatened by this constant stream of filth. Minnesota Waltonians have fought valiantly to compel the metropolitan area of St. Paul and Minneapolis to erect adequate sewage treatment works, and farther down the river, where the same unsavory conditions prevail, Winona and LaCrosse are striving to accomplish similar objectives.

While the effects of pollution have not been so pronounced in many portions of the West, a glaring example of the destructiveness of paper mill wastes is apparent on Puget sound. Here is found the famous Olympia oyster, acknowledged as a delicacy to tempt the most epicurean taste, and a food resource of considerable value. An investigation by the U. S. Bureau of Fisheries in 1930 revealed that 70,000 gallons of sulphite liquor were being dumped into Oakland bay, and that this contamination was actually ruining the oyster industry. After strenuous efforts to secure cooperation of mill operators, they agreed to distribute waste liquors to keep them out of Puget sound, and a fund was raised with which to pay damage claims of oystermen in Oakland bay. This same source of pollution threatens the valuable salmon industry in Pacific coast waters.

With the damage to streams in the east by both municipal and industrial sewage as poignant examples of abuse, it is hoped that the west will take heed before too late to protect their own magnificent waters from despoliation.

New York has permitted her harbor to become the most polluted in the world, and no wonder when one realizes that raw sewage from a population of over 7,000,000 persons and the trade wastes of over 100,000 industries are discharged into the harbor and coastal waters with practically no regulation or control. A once thriving fishing and shellfish industry has been ruined. Control of pollution entering

New York harbor comes under the jurisdiction of Connecticut, New Jersey and New York, which has complicated the matter, but during 1931 the legislatures of these states provided means for the organization of a commission to devise suitable plans for handling the pollution problem. The city of New York now has plans under way for the erection of a $30,000,000 sewage system which will serve one-fifth of greater New York.

There is now pending in Congress a measure to amend the Oil Pollution Act of 1924 so that its provisions may extend to all waters over which the United States has jurisdiction; that is, all navigable waters and their tributaries so far as affecting navigation and commerce, public health, fisheries and migratory birds. The disastrous effects of oil pollution are felt all over the world. This source of contamination has impaired the fishing industry and is a contributing factor to the decrease of waterfowl, and their feeding and nesting areas. This measure should be passed as speedily as possible.

The Izaak Walton League has been represented in these several projects and feels it has had a worthy part in crystallizing sentiment and arousing a realization of the menace of polluted waters.

How Much Do Clean Streams Cost?

"How much do clean streams cost?" is the question which immediately arises when a community is considering correction of local conditions, to which is answered that no fair estimate can be made until a thorough survey of the individual problem has been made by competent engineers. However, we can quote figures on construction and operating costs in various cities. Dr. W. D. Hatfield, Superintendent of the Decatur, Illinois, Sanitary District, quotes costs showing that for complete treatment of sewage by plants operated in Atlanta, Baltimore, Columbus, Fitchburg, Lexington, Lincoln, Urbana and Marion, the average construction costs were $9.60 per capita, and from $7.00 to $14.00 per capita for plants of a different type located in Milwaukee, Indianapolis, Houston, etc.

The operating cost of nine complete plants throughout the United States varies from eleven cents to fifty-five cents per capita per year. So you see clean streams are not in the luxury class, and sewage treatment works can be operated as a public utility—service charges apportioned according to the property owner's share of sewage waste.

Because public opinion has not demanded industry to make provision for disposal of wastes, it has been loathe to make large expenditures for treatment. However, this situation is changing and industry itself, in some instances, is faced with the necessity for clean water with which to operate factories.

It has been stated by scientific authority that all wastes can be treated, and it has been proved that the treatment of some wastes results in a profit to the manufacturer. Dr. A. M. Buswell, Chief of

the Illinois State Water Survey, cites as an early example pollution of the air with acids from soda manufacture. Today the acids which are recovered are more valuable than the soda itself.

Another example is the manufacture of charcoal and coke. In both of these industries in the early days the custom was to discharge the tars directly into streams causing great harm to all plant and animal life. Now many of these plants are operating for the sake of the chemicals which can be recovered from the tars and oil distillates. The charcoal and coke are really by-products.

Packing house wastes are being successfully recovered, and one starch factory is now manufacturing from its waste material a valuable product worth more than $30,000 a year, where formerly poisonous liquors equivalent to the sewage from more than a quarter of a million people were being discharged into public waters.

Industrial research to determine practical uses of wastes has definitely helped on such problems and activities along this line should not only be encouraged but insisted upon.

Wastes from mines and pulp and paper mills are among the most deadly with which public health officials, recreationists and industrialists have to contend. Of the organized industries, the pulp and paper association is the only one which maintains an engineer in the field whose job it is to encourage treatment of wastes and to cooperate with individual mill operators in determining means to that end. Since the paper and pulp manufacturers are among the worst offenders both in the East and in certain parts of the West, we should see to it that they actively continue efforts to find adequate methods of disposal and treatment.

The Milwaukee sewage disposal plant, one of the largest, if not the largest activated sludge plant in operation in the world, manufactures a commercial fertilizer in large quantities and actually markets it successfully. The average return up to a few years ago was $15.00 a ton, which assists materially to reduce annual operating expenses.

From experiments conducted recently at the Dayton, Ohio, plant, it developed that the production of certain garden truck, including lettuce, parsnips, radishes, turnips, tomatoes, lima and string beans, beets, etc., was stimulated and improved by the use of sludge as fertilizer. The sludge from that plant was furnished without charge to farmers interested in securing it as fertilizer. In time many more municipal plants may develop revenue producing products which will aid in reducing treatment costs.

Local Clean Streams Activities

As public officials and conservationists and anglers many of you have participated in the development of anti-pollution programs and are familiar with local activity in this connection. However, I

should like to cite a few examples of what has been going on during the past couple of years in the various states.

California chapters have been cooperating with other civic groups in efforts to bring about abatement of oil pollution along the Southern California Coast, where much damage is resulting to fisheries and recreation.

The Coeur d'Alene river in Idaho receives directly and through its tributaries wastes from some of the largest silver-lead mines in the world. We aided in securing proper contacts for a state commission created to study conditions, and in 1931 a cooperative survey by state and federal agencies was made to determine methods of relieving conditions.

In Illinois, chapters have been responsible for the establishment of a number of sanitary districts, and are in constant touch with the Sanitary Water Board. At the present time towns along the Kishwaukee river are getting organized to construct sewage disposal plants. Chapters along the Fox river, picturesque stream once abounding in fish life and offering recreation to a great metropolitan area, are doing their utmost to organize a campaign to clean the Fox. The Cook County Clean Streams Committee, representing something over twenty chapters, is concentrating efforts on cleaning up the Des Plaines river and other streams in the Chicago area. They are a recognized civic group and mean business.

South Bend, Indiana, has again taken up the cudgel to force a clean-up along the St. Joe river, and will petition the federal government for funds with which to build sewage works.

For the past year the Raleigh, North Carolina, chapter of the League has sponsored radio talks on conservation and stream pollution in an effort to develop public interest in woods and waters. Largely as a result of this educational campaign modern sanitation legislation will be presented in the 1933 Legislature, and the city of Raleigh will build a treatment plant.

Waltonians have directed attention to the industrial pollution of the Willamette river in Oregon, famous for Chinook salmon. A survey has been made and information made available will be the basis of efforts to secure legislation to develop a ten-year program for prevention and elimination of pollution from Oregon streams.

The Pennsylvania Division has waged a strenuous campaign for several years to secure more effective pollution laws.

Through an intensive statewide anti-pollution program sponsored by the South Dakota Division, some of the largest towns in that state, located along the James river, have been forced to cease dumping their sewage into this stream by erecting modern treatment plants. During the past few months, Watertown, on the Big Sioux, dedicated its new plant, a direct result of local activity.

One campaign which promises to be most vigorous and fruitful of results is that affecting the Tidewater area of Virginia. As a result

of a conference sponsored by the Norfolk Chapter in August, a special committee was authorized to study pollution conditions and make recommendations for remedying matters. The personnel of this committee is made up of mayors of Tidewater cities, representatives of the U. S. Public Health Service, the State Board of Health, State Commission of Game and Inland Fisheries, Commission of Conservation and Development, the fishing, shellfish and industrial interests, the Association of League Chapters in Virginia, and the Norfolk Chapter.

Effective action in the regulation and control of water resources, in the final anlysis, is possible only through suitable statutes, honestly administered. The purpose of laws is to protect clean waters against menace; eliminate filth and improve waters now polluted; and to render water resources increasingly useful to the public as sources of municipal water supplies; sources of water for industry and agriculture, and places for recreation, including suitable habitat for aquatic life with which we as fish culturists are concerned.

Back in 1928 the League presented a request in the form of a resolution to a conference of State Sanitary Engineers, held in Chicago, to consider the development of a model sanitary law. The conference was loathe to prepare or suggest an outline, feeling that no draft would be applicable to every state. Since that time a study has been made of the sanitary laws of many states, and we have available a draft of a Municipal Disposal Act, the provisions of which will be applicable to any state if altered to fit local constitutional provisions. The principal feature of this suggested form is the financing of sewage works with funds derived from service charges; that is, municipalities may construct and operate treatment plants as public utilities. Michigan and Ohio have such acts in operation.

It seems rather wise to concentrate efforts in some cases on municipalities, since it would naturally follow that action by them to provide proper waste disposal would force industry to follow suit. At the same time it has been found that state and government institutions have been notorious offenders and any campaign must be aware of this source of pollution, else there is little use of demanding a clean up on the part of municipalities and industry while institutions continue to appropriate the public waters for sewers.

Considerable activity is evidenced at the present time throughout the country stimulated by provisions of the Emergency Relief and Construction Act providing loans for self-liquidating projects. Many cities are ready and willing to build plants, but in many cases due to legislative restriction the problem of financing has seemed hopeless. In states which permit operation of sewage works as public utilities, Michigan and Ohio for example, funds may be borrowed from the Reconstruction Finance Corporation for financing treatment

projects. Many other states will pass the necessary legislation which will enable them to take advantage of this opportunity.

Indiana is the first state to avail itself of this provision of the Emergency Relief and Construction Act by adopting an enabling act during the special legislative session recently closed. Already some seven or eight cities in that state have made application for funds.

We are informed by representatives of the National Committee on Trade Recovery, which is directly sponsoring construction programs and with which we are cooperating, legislation will be presented in Massachusetts, Connecticut, Rhode Island, New Jersey, New York, North Carolina, Virginia and Wisconsin. An enabling act is now pending in the special session of the Illinois legislature. Certainly no other type of public works offers a better combination of usefulness and employment than the construction of sewage disposal facilities. The campaign for clean streams is gaining impetus, and the time is auspicious for securing modern statutes and modern methods of waste disposal.

In the words of Grover Ladner, a champion for the restoration of streams in the Keystone state, "If the people will it that the streams shall be clean—IT CAN BE DONE."

Discussion

DR. FIELD (Massachusetts): We cannot emphasize too strongly this suggestion with reference to the development of public utility companies. That has been done already in Germany, very successfully, so much so that in certain places they have been able to utilize the sewage by extracting from it the methane gas. It has also been done in some states in this country. In addition to that they have developed a fertilizer which they sell to the farmers, or allow the company to use for developing their own land.

As a final step, after the sewage has been purified, the companies use a material mixed with two parts of river water for raising fish. By that I mean that the material in solution in the purified effluent, mixing the sewage water with river water, is sufficient to increase the normal yield of fish from 500 to 1,000 pounds to the acre. The whole thing is done in a large way on a commercial scale. The nets are emptied right into an elevator, the elevator goes on to the tank cars and the cars go on to Berlin and the market.

We are doing practically nothing in this country along that line. It may be interesting to note that this country spends $300,000,000 for the purchase of nitrates from Chile and other countries, whereas we turn our own waste nitrates into the streams. By way of showing what can really be accomplished in that respect, I may point out that in 1929, the last figures available, the city of Milwaukee alone salvaged $600,000 worth of nitrates which they sold to commercial companies.

MR. FOLLETT (Michigan): Several years ago I visited the great sewage plants in Berlin, and I can say that what they are doing there can be done in every city in the United States and Canada. There are two very important aspects of this serious problem of stream pollution. There is the waste of solid matter or sludge that is being discharged from the great cities and that is needed in the economy of nature to restore the fertility of the soil, and there is the destruction of valuable fish life and of aquatic and vegetable life as well. The problem is a difficult one, because you must deal with politicians in all the great cities, and in the majority of cases they are not capable of apprehending the importance of the considerations involved. Then since the manufacture of the automobile to the extent of its recent commercial development the effects of the action of mineral oils have come into the picture to a tremendously increased extent. When mineral oils come in contact with the solid sludge, they have the effect of arresting the process of decay, and during the slow process of neutralization the oxygen is taken from the water, with fatal results to fish and vegetable life. This condition is carried on and on until our waters are polluted to such an extent that valuable food fish are being exterminated.

DR. MAGEE (Washington, D. C.): I am glad of this opportunity to give the members firsthand information with regard to a health survey that is now in progress and a tentative report that has been made to the United States Park and Planning Commission by the U. S. Department of Health. The report has to do with the condition of the Potomac river. For fourteen years the District of Columbia has waited patiently for a biological survey, urged by such organizations as the American Game Association and the Izaak Walton League of America, and a public sentiment in regard to the matter has been aroused irrespective of the diverse political opinions of those who go there to legislate for us. The result of this investigation showed that the condition of the Potomac river is simply intolerable. The National Health Institute has gone on record as establishing beyond a doubt the fact that this condition must receive the attention of Congress. I hope the ladies and gentlemen who are present will go back to their homes with the determination to follow up this campaign by urging those who go to Washington to do what they can to clean up the capital of this country in accordance with the culture and magnificence it is so proud to boast.

MR. DENMEAD (Maryland): The city of Baltimore has established, at a cost of approximately $50,000,000, both the sanitary and the storm system. We do not allow anything to go into the storm sewers but water. All solid water, oils and so on, go into the sanitary sewer and are disposed of in the disposal plant, while ordinary water goes into the storm sewer. The result has been the removal of pollution from our waters, and we have fish and crabs in the river within a few miles of the city.

OUR FIGHT FOR THE BLACK BASS

RAYMOND MILLER
Williamsport, Md.

"Our fight for the black bass" is a timely and important topic to all anglers who sooner or later make contact with that great American game fish. It requires all the strategy and skill of the angler in matching wits with this game fighter, and it is likewise going to require strategy and skill to win the fight for black bass protection.

We are fighting to give black bass the right to live and propagate and flourish. We are fighting to save this aristocrat from being exterminated by commercial methods. We are fighting to preserve for our children and for future generations that wonderful outdoor pastime, that God-given privilege of communion with Nature along the banks of our favorite fishing streams.

We feel therefore that this fight is necessary and worthwhile, and that the results to be accomplished will justify the time and effort put forth, because the black bass of any state are worth approximately $2.00 per pound to the angler. That is the amount expended by the hook and line fisherman for the hire of guides, boats, bait and equipment, while the net fisherman usually receives from 5c to 20c per pound. I believe you will agree with me that the saving of this great game fish for the angler will mean much more to any state than to permit this species to enter the commercial catch.

Food fish for commercial purposes in the Chesapeake bay country are plentiful and black bass are the small part of the commercial catch. Statistics from the Bureau of Fisheries show that the catch of black bass in Maryland in 1920 amounted to 77,388 pounds, valued at $18,969.00; in 1925, 35,609 pounds, valued at $6,760.00, and in 1930 to 14,321 pounds, valued at $2,632.00, or a decrease of approximately 80% in ten years. Do not these figures show conclusively that the supply of this species is rapidly becoming depleted? State and federal governments and sportsmen's organizations contribute time and money in a vigorous restocking campaign, in order to perpetuate the supply of this great game fish in Maryland waters. It is contrary to state and federal policy to continue propagation and restocking in a state which does not afford adequate protection to the species propagated.

Much has been accomplished in the way of federal regulation and protection and a great deal of credit is due Senator Hawes and other leading conservationists throughout the country, who worked untiringly to secure passage in congress of the national act known as the "Hawes Black Bass Bill," which paved the way and made effective the acts passed by a number of states closing their markets to the

transportation and sale of black bass, but much remains to be done by other states in passing protective legislation and uniform regulation of open seasons for angling, and limits as to size and number.

Maryland with its splendid bass streams and natural environment, exploits her bass in a commercial way, I am sorry to say, during eight months of the year, the market being closed only during April, May, June and July to commercial sale. Anglers know that commercial fishing is at its best during the winter and early spring months when bass are sluggish and are easily taken in nets. Our sister states of Virginia, West Virginia, Pennsylvania and the District of Columbia prohibit sale at all times, and Maryland under its present law becomes the dumping grounds for black bass, bootlegged in from other states. This is not fair to the anglers of those states who have worked hard to prohibit sale within their own borders, and the only remedy for the indiscriminate slaughter of black bass is to close all markets to commercial sale. Law-makers are beginning to understand that where there is one commercial fisherman, there are 500 who fish for recreation and sport, and it is estimated that there are thirty men who fish for black bass to one who fishes for any other variety of fresh-water game fish.

A bill was introduced in the 1931 session of the Maryland legislature prohibiting the transportation and sale of black bass. It passed the lower house but failed of enactment, largely through the influence and opposition of the President of the Senate, who held the bill in committee during the closing days of the session, despite the vigorous protests of the Conservation Department, the Bureau of Fisheries and conservationists of the state. A 1932 report from the Bureau of Fisheries indicates that nine commercial fishermen in Charles county, from which most of the opposition comes, have shipped only 2,625 pounds of black bass during the season, valued at less than $500.00, so that the taking of these bass does not produce a livelihood for these nine men.

A bill will again be introduced in the 1933 session of the Maryland legislature, prohibiting the commercialization of black bass and we have been assured of the hearty cooperation and support of the Conservation Department and the Bureau of Fisheries as well as organizations and individuals throughout the state.

The fight will require thorough preparation and diligent effort if we are to win the battle, and my suggestions as to preliminary work on the bill before the legislature convenes, and afterwards, are as follows:

First: An educational campaign amongst organizations as well as individuals, through the press and to members of the legislature.

Second: Personal contact with doubtful legislators.

Third: Early introduction of the bill into the legislature with vigorous support and follow-up through committee, before it can become a trading medium or political football, as often happens to-

ward the latter part of the session. In connection with this, would suggest that at least three or four members of each branch of the assembly should be converted into active workers or supporters of the bill, men who will take the floor and fight for the bill all the way. In addition, anglers should be selected from the doubtful districts, who will appear, to offset the testimony of the commercial fishermen in committee hearings.

Discussion

MR. E. LEE LECOMPTE: I sincerely hope that at the coming session of the general assembly we shall be able to secure the enactment of legislation prohibiting the sale or transportation of black bass.

Mr. Miller referred to the sale of black bass in the state and the amount of income derived therefrom by the commercial fisheries. We claim that the black bass for angling purposes is worth a dollar a pound, whereas on the wholesale market it brings from fifteen to twenty-five cents, as a rule fifteen, because they are shipped in the spring of the year, February 1st to April 1st, at a season when the market is well supplied with other fish.

I wish to read to you a little article which appeared in "Maryland Fisheries," a publication of the Maryland Department to which our Conservation Commissioner called your attention this morning. The title of it is, "Anglers Profitable to Bay Country," and it goes on to say:

> "According to figures gathered by deputy commanders of the Maryland Patrol Fleet covering a period of one week, from August 22 to 29, 2,621 trips were made from the major fishing resorts of the Chesapeake bay, and 16,805 persons engaged in the sport. At an average cost of $8 a boat trip, the watermen who hired their boats received $20,968. It was estimated that approximately half of these pleasure seekers remained at boarding houses and hotels for two days, spending approximately $5 a day, which would mean that they put $83,190 in circulation for that item alone. There is no means of knowing how much additional money was spent for bait, or gasoline for their automobiles. Roughly, it may be said that anglers resorting to Maryland waters spent in the neighborhood of $100,000 a week in pursuit of their favorite sport."

Our claim is that if we can bring about the enactment of legislation prohibiting the sale or transportation in or out of the state of black bass at any season of the year we will add greatly to the revenue of the boatmen who are interested in the commercial fisheries.

MR. GORDON (Washington, D. C.): I notice that the value of the black bass per pound for sporting purposes varies a great deal. Commissioner C. C. Woodward, of Florida, estimates that as a lure to attract anglers, the black bass is worth $5 per pound in Florida. Seven hundred tons of black bass are ordinarily taken out of that state each year for commercial purposes, which at $5 per pound means about $7,000,000. At twenty cents a pound for market purposes, which is considerably beyond the price the commercial fisherman ever gets, the income from this same seven hundred tons of bass would be only $280,000.

SALMO SALAR OF THE ST. LAWRENCE RIVER

RICHARD FOLLETT
Secretary, Detroit Zoological Society

Von Humboldt once said that history is the exhibition of things that happened. The purpose of this paper is to give a brief account of what has happened to the salmon of Lake Ontario and the Upper St. Lawrence during the past century.

Today very few people know Lake Ontario was once the greatest salmon lake in the world, or that salmon even existed in these waters, or that the St. Lawrence was once the greatest salmon river in the world, considering all its tributaries. The earliest reference to salmon of Lake Ontario I find in the year 1654, at the time of the second visit of the Jesuit missionaries, Fathers LeMoyne and LeMercier, to the Iroquois Indians at Oswego.

I have before me a paper read at the May meeting of the Royal Society of Canada in 1930, by Dr. W. Sherwood Fox of the University of Western Ontario, the title of which is "The Literature of Salmo Salar in Lake Ontario and Tributaries." It is the most complete and interesting document on this subject that I have ever seen.

In 1833 an Irishman by the name of McGrath, who lived at Erindale on the Credit river, writes: "I have taken in the River Credit in the spring, within twenty rods of our hall door, as fine salmon as ever I met in Ireland, and as firm and full of curd as if they were within ten miles of the sea instead of five hundred." Erindale is about twenty miles west of the City of Toronto. There are similar accounts of the abundance of salmon in the rivers in the vicinity of Toronto, namely, the Humber, the Don and some of the smaller streams. These can be had in reading Dr. Henry Scadding's book, "Toronto of Old." As late as 1873 Mrs. Simcoe, wife of Governor Simcoe, notes in her record of November 1st that during the early evening of that day a quantity of salmon were speared in the River Don adjacent to Castle Frank. Of course these fish were killed on the spawning beds. Dr. Scadding reports that the annual catch on this river amounted to many hundreds. He also gives an account of the abundance of salmon not only in the rivers in the vicinity of Toronto but in the bay itself, and that he was once a member of a party which in the course of one hour speared some twenty heavy salmon.

Dr. Fox referred to the Port Credit river as the "Salmon river par excellence," but the salmon disappeared in this river nearly a century ago, owing to the fact that Port Credit was an important shipping port and there was more grain and lumber shipped in the early part of the last century than at Toronto.

I have recently visited Port Credit and interviewed some of the older settlers. One man, eighty years of age, said that salmon disappeared when he was a small boy, but he remembered of his father going up the river one night after a number of sailors who had gone up to spear salmon, and that he was able to pick up enough floating salmon in the river, that is, wounded fish, to fill his boat. Of course soil erosion which followed the destruction of the forest had a very potent effect upon the extermination of the salmon, together with constant fishing, for the river was fished from early spring until late fall.

Dr. Fox gives accounts of the salmon in the streams which flowed into the Bay of Quintte. Some of them were excellent streams, probably as important as the Don and the Credit, and he said, "I could quickly weary you with a recital of the names of numerous creeks visited by salmon." There were probably more than fifty streams between Hamilton and Kingston that salmon frequented at some season of the year.

On the New York side salmon were probably more abundant than on the Canadian side, for the reason that the rivers were larger.

According to records in 1817, a dam was built across the Genesee river at Rochester, by Elisha Clark, and more than 100,000 salmon were killed with clubs, spears and pitch forks below this dam. This of course ended the salmon of the Genesee river for all time.

In July, 1654, Father LaMercier and Father LeMoyne arrived at what is now Oswego, on the verge of starvation. On this account they named the place "LaFamine," but, says Father LeMoyne, "soon after our arrival the Oneida Indians came down the river with their canoes filled with fresh salmon. Then did He at that time make us experience the truth of his promise, for on that very night one of our men caught twenty large salmon, and on the way up the river our people killed thirty other salmon with spears and paddles. There were so many of them that they were struck without difficulty." Other similar quotations can be had from Jesuit Relations and other literary sources.

There is no doubt that salmon at one time literally swarmed in the three largest rivers, namely, the Genesee, Oswego and Salmon, and if the Port Credit river was the salmon river "par excellence" of the Ontario side, the Salmon river in New York, which entered Lake Ontario at Port Ontario, was the salmon river "par excellence" on the New York side.

You will find in Dr. Goode's report of 1872 a letter from Mr. Harrington who lived at Pulaski, who stated that 3,600 salmon were killed in one night on this river, and he adds this significant paragraph: "The salmon here at one time brought more money to the people than all the machinery on the river." I have recently visited Pulaski, where I met Mr. Clark, President of the bank, a man eighty years of age, who told me that as late as the 70's salmon were still

abundant in the river, and at that time they thought they would always have them. He said when the first dam was erected the fish had no trouble in going over during high water, but the second and third dams prevented their ascending the river for all time. Salmon ascended the Oswego river as far as Finger lakes. Seventy-five years ago farmers near Baldwinsville, New York, actually threw salmon out of the Seneca river with pitch forks, so dense were the shoals of fish at that time.

Salmon were abundant in the Upper St. Lawrence and its tributaries, from the outlet of Lake Ontario to tidewater. They entered Lake Champlain and its tributaries, the Saranac river at one time being famous for the abundance of its salmon.

In 1841 Sir Richard Bonnycastle states he saw salmon being speared near Cedar Rapids, thirty-two miles above Montreal. They entered the St. Francis, the Rivre Au Saumon, not far from the New York boundary, and practically all the streams on the south side of the St. Lawrence as far as the Gaspe Peninsula; in fact, there are two rivers, namely, the St. Anne and Madeline, which are excellent salmon rivers today, and on the north side the salmon rivers extend way beyond Labrator, in fact beyond the Arctic Circle.

In the early 60's Samuel Wilmot built a salmon hatchery on what is known as Wilmot stream, about forty miles east of Toronto. This hatchery was operated successfully for twenty years, until the supply of fish failed. In 1866 Mr. Wilmot records having gathered 100 grilse from Lake Ontario and taking them into the hatchery. The Wilmot stream was formerly known as Baldwins creek. It is a comparatively small stream, but at one time thousands of salmon entered this stream in October to spawn.

In 1873 Mr. Wilmot sold to the New England fish commissioners some thousands of salmon eggs taken from this stream, and the price stipulated was $20.00 per thousand in gold.

In conclusion, I again quote from Dr. Fox: "The Ontario salmon has no longer a home wherein to rear its progeny, and all that remains is a name to warn us as a nation against the wanton destruction of a rich inheritance." They have gone the way of the Labrador duck, Eskimo curlew, great auk, passenger pigeon and Michigan grayling.

During the next year it is my purpose to study carefully the old records of Ontario and Quebec, the colonial and county records of New York, and also to give an account of the commercial fishing down the St. Lawrence, where nearly all the salmon, i. e., *Salmo Salar*, are taken at the present time.

BIOLOGY AS THE PANACEA FOR SOME NATIONAL PROBLEMS

GEORGE W. FIELD
U. S. Biological Survey

It is a special pleasure to be in Baltimore, because the real work of the continuing study of the biology of water was started at Johns Hopkins University by Professor W. K. Brooks. I came here in 1888 and remained until 1892. At that time the Chesapeake Biological Laboratory was in operation, under the direction of Professor Brooks. Professor Brooks used to say that the best part of Maryland was under water, by which he meant that the possibility of developing the water was far greater than the possibility of developing the land. That is still true, even more today than in his time. Professor Brooks continued the work of Professor Louis Agassiz of Harvard, who carried on his marine researches at Newport and Cape Cod. At the Johns Hopkins University also was Professor H. Newell Martin, a lineal descendant in an academic sense of Professor T. H. Huxley in England, so that at Baltimore was concentrated the best knowledge of the aquatic biology in the world.

When in 1885 I told Professor A. S. Packard, of the Faculty of Biology at Brown University, that I wanted to enter upon a study of water and water organisms, he said: "Oh, don't do it; there is no possibility of making a living at it." I went to the President, Dr. E. G. Robinson, and he said: "Young man, follow your bent. It is a great thought, and the time is coming when the principles involved will be fully recognized and needed. After all, service is the biggest thing in the world and is worth more than money." But the soundness of Professor Packard's position has been amply demonstrated. It is still difficult to make a living at this sort of study; and to carry on I have been obliged to decline commercial offers with attractive remuneration. But I have kept to the line of scientific investigations, correlated with the business aspects and projects, ascertaining how business should be carried on in order to maintain these valuable assets as a permanent course of national development.

The laws of nature are today actually menaced by certain erroneous principles of business and of politics, particularly when adversely affecting the maintenance of the public waters in quantity and quality. The quantity is being threatened by commercial interests which have found it financially advantageous to impress upon the farmers that by drainage of the prairie lands in the West they could get better returns from the production of cereals, such as corn and wheat. And so the farmer, instead of adapting the crop to meet the conditions and requirements of the soil, has made the funda-

mental mistake of modifying the soil to meet the requirements of his crop. The result is that he has a tremendous overhead by reason of his investment in draining and otherwise modifying his land for the production of cereal crops, and thus we have a surplus of cereals and an enhanced cost, with a decline in the supply of protein food in the form of wildfowl and fish.

True conservation may be described as a modification of existing business and political practices so that in the pursuit of permanent rather than merely transitory economic advantages they shall conform to Nature's laws. An ideal and adequate conservation policy, for example, should so conform to the laws of nature that ultimately all factors shall become so adjusted that the basic functions of the soil, water and atmosphere cannot be impaired.

Secondly, there is the menace of pollution. We have acquired the habit of turning into the public water courses everything we do not want, with the result that our streams and public waters are polluted to a very serious extent. We are wasting among other substances vast quantities of nitrogen which is the most important and costly plant and animal food. To show the extent to which we are wasting our nitrates, as a nation, we pay for the purchase of nitrates about $300,000,000 to Chile, Germany and other nations annually. The city of Milwaukee in 1929 salvaged $600,000 worth of nitrates and sold them under a trade name to a fertilizer distributing corporation, which in turn sold them to the farmers. Milwaukee is only one of a hundred or more cities that are turning vast amounts of pollutants into the streams. And whereas Milwaukee is putting into the water courses the nitrogenous waste of only about half a million people, there are more than thirty million people wasting nitrates into the public waters of the United States.

It is estimated that the aggregate wastage of water, soil, and atmosphere is costing North America no less than six billion dollars every year, which is about half the value of the entire agricultural products of the United States. The farmers are the ones who lose that entire six billion dollars, but the shock of the loss is nation-wide because this wasted capital is needed in business.

As a further specific menace the cycle of water has been disturbed by the introduction of drainage and the resulting lack of evaporation of the water into the atmosphere. The normal cycle of water is visualized as coming from the air and dropping on the soil, whereupon a certain portion runs off. We have enormously increased that run-off. Man can plan to soak a larger proportion into the soil and let it come back out into the air by evaporation and through vegetation. The vegetation pumps that water out from the water table, it evaporates into the air, then it cools and comes down again; thus there is a constant and more or less regular cycle of water. This water carries with it ingredients of plant food. The chemical ingredients are transferred under the influence of sunshine first of all into

minute vegetation, in the form of bacteria, diatoms, desmids, etc. These in turn are eaten by minute animals, notably infusoria; the infusoria in turn are eaten by crustacea, and the crustacea are eaten by fish. Thus non-living materials are converted into living materials suitable for human foods. It is quite evident, therefore, that business is based on this cycle of matter; and that if you disturb that cycle of matter you disturb business because you disturb life.

Now, the water that runs off from the land is utilized in the shallow estuaries of the coast in an interestingly important way. Not only does it furnish food in the form of vegetation and microscopic animals, but the entire life cycles in these waters are regulated, since other forms of life come up closer to the shore because they find the water of that specific gravity which they normally require. We know that changes in the volume of the flow of the Mississippi river modify the human food supply which comes from the Gulf of Mexico in marketable quantities, such as shrimp, oysters, tropical fishes.

So it is in Chesapeake bay. When you reach the stage where the amount of water that runs into the bay is smaller than it should be, the enemies of the oyster and the crab will come closer to the shore to the damage of the industries. Oysters and other similar forms can stand fresh water, but their enemies cannot. That has been shown in many cases. So that the maintenance of the normal water run-off from the land, whether it comes from springs or from the rivers, is an important asset to Maryland or to any other coastal state.

In crossing the country from the west coast to the east it will be observed that the water table everywhere has dropped. The maximum drop is perhaps in North Dakota, where it is upwards of fifty feet; if you have occasion to dig a well for the purpose of getting water you have to go fifty feet father than you did thirty years ago. In Ohio the drop has been about twenty-five feet in the Muskingum watershed, the largest of the several tributaries of the Ohio river, which in turn is the cause of more floods than any tributary of the Mississippi. Coming to Maryland and Virginia, I am told that the retreat of the water table is now about fifteen feet. Even New England suffers.

The reason for all this is that we are taking away from the water table by drainage, by wells for municipal water supplies, for factory purposes and otherwise, great quantities of water which formerly carried on a biologic function; and in addition much is taken for purposes of power and navigation which unnecessarily limits to some extent biologic uses.

It is our claim that the same amount of power and the same amount of navigation would be made available if we first allowed that water to perform its biologic functions and then used it afterwards for these other purposes. We are seeking to develop a method by which that can be done. If the flood water in the form of run-off from 20,000,000 acres were held temporarily impounded and kept

in its biologic functions on land in the Mississippi valley and then distributed for power and navigation, and other uses on the Mississippi river, the flood problem from Cairo to the Gulf would be solved for all time. The water would serve normal biologic purposes on the watershed up the river, and the future of farming and of business and climate would be reasonably secure. Moreover, the farmers would be relieved of a great burden and business would be promoted and correlated with the regulated supply.

The construction of flood control reservoirs was found by the engineers to be too costly. But the biologist studied the possible utilization of the waters impounded for flood prevention. A year ago I went over to France and Germany in the interests of the Department of Agriculture, returning a few months ago. I found there that the farmers had frequently the same problems as we to deal with, but that they had met them, largely as a result of experiments extending over the past hundred years.

In certain regions the flood problem is controlled by the landowners themselves who need and who actually treat that water as their business asset. In France this particular kind of operation is being carried on successfully with the waters of the river L'Ain, which is about one hundred miles west of Geneva. The L'Ain is a tributary of the Rhone. This terrain resembles much of the Mississippi valley. It comprises a territory which is worked very much like our own prairies, is divided up into areas with small tenant farms but many large landowners.

They have solved the problem, as we can do here, by confining the water by means of dikes of their own construction, about four or five feet high but with little excavation of this surface of the land. After a short time the cycle of matter develops plants and animals which serve abundantly as fish food. They stock the ponds in the same way that we do, with small fish, using the carp, the poisson blanc, which is like the deep water minnow that has been introduced into this country, the pickerel, the taench, and the rainbow trout; so that they have a cycle of two herbivorous and three carnivorous fish. These ponds vary from two acres to seven hundred acres in size, averaging about eighty acres.

In our case by increasing the number and suitable size of our ponds we could use farm machinery, and thus carry on an extensive scale rather than we do on the present intensive scale. We have small fish ponds, but they have the large ones. The minimum yield is about one hundred pounds to the acre. It costs them nothing and their land is being improved continually. This is all done in a cooperative way, a principle which should be carried out here by guiding the cycle of matter, as is done in scientific agriculture.

The question may be asked, can this plan be carried out in this country? I have just made a 7,000 mile trip through Ohio, Indiana, Illinois, Missouri, Kansas, Nebraska, through to North Dakota and

back through Minnesota and Wisconsin. There are vast areas in each of those states which could be handled in this way. Here is one of the biological solutions for our farm problem, a new type of rotation of crops.

We are accustomed to rotation of crops by the use of clover, grass, potatoes, corn and so forth, but here is a rotation involving the prime elements of water, soil, atmosphere, control of disease and insect pests; one year being devoted to grains of cereals, garden crops and two or more years to such aquatic crops as wildfowl, fish and so on, making these latter an annual protein crop, in part in the form of recreation marketable by the farmer, all built up from materials now largely wasted.

In France and Germany they keep the land under water for two years, raising fish; the third year it is drawn off, perhaps into some pond nearby or farther down the stream, the surplus water being available for power and navigation. So there is a new development for the farmer and for the fish culturist, and a new method for control of such pests as cutworms, grasshoppers, mosquitoes by making them to be food for fishes and wildfowl.

Can that be carried on on a commercial scale? Germany has developed the commercial aspect of it to a much greater extent than has France. Germany utilizes the sewage of the cities for raising plant food for fish. The water is fertile, manured as well as the land. The French people place a suitable type of manured material in beds, nursery pools, and thereby develop various forms of animal and plant life. In some of the German cities, to one part of the purified sewage effluent containing the nitrates in solution is added two parts of river water; the mixture is run into the ponds, the size depending upon business potentialities. The first crop is Lemna, the "Duck Weed." The ponds are built in an interesting way. They are built above the original surface of the ground; the constructors' workmen back the rail construction cars in, filled with gravel, and build an embankment four or five feet high; this they build up entirely around the pond. They keep these tracks and when the fish are developed ready for market two years later the netted fishes are thrown into scoops, lifted and dumped into the tank cars, which are hauled by locomotive to Berlin or other markets.

After the fish are collected the water of the pond is still further drawn off, and after a day or two the ground is ready to disc-harrow. If in the spring, they sow oats; if in the autumn, rye or wheat. While the fish are growing the soil is being fertilized, biologically, the water table is being restored; consequently by this method the farmer gets a larger profit from the fish than he does from either grain or cattle which are fed on the grain crop. The practical result is that such farms are worth about $20 an acre more than land which is not treated, so that the farmer gets that benefit for himself.

It is a real biologic development of the cycle of matter for busi-

ness purposes, wherein the wastes of civilization are turned into food. That is the end use of the tax for sewage. Sewage becomes an asset instead of a liability. The sewage is used first of all to generate illuminating and heating gas and is sold to the city. After that the sludge is sold to the farmers. They have developed public service corporations which relieve communities from taxation for sewage and garbage disposal and, as an end product, sell at a profit the salvaged material to fertilizer companies and also utilize for water power the purified and biologically utilized effluent. I believe the same can be done in this country by proper experimentation and with proper regulation. The method should be by public service corporation under government regulation. We have all the facilities, to an even greater extent than either Germany or France.

Let me, in closing, give a partial list of some of the national problems for which a biologic panacea is already available as soon as there is awakened the popular consciousness that water, soil and atmosphere, kept in normal conditions of biologic cooperation, are the basic raw materials of life; and that man-made floods, droughts and pollutants check the biologic cooperative-process, or cycles of matters, which make our local and national prosperity. Present practices have increased taxes to the tune of $6,000,000,000 annually—equal to $50 per person for each man, woman and child in North America. These taxes can be greatly reduced by utilization of biologic methods, and by making our business and politics conform to Nature's laws.

Of the compound factors involved, the largest item is the conservational control of the run-off water. Because lack of such control is the cause of floods, droughts and irregularity of rainfall. Consequently farming becomes a gamble. Business development is limited by the quantity of water available in places and time. It is the velocity of the run-off water which determines the erosion of the land surfaces, with the loss of tillable soil and chemical elements of soil fertility. It is the lowering of the surface of the ground water (water table) which induces drought conditions. Drought slows up, or even may stop the cycle of matter, as do also floods and pollutants. Because of the decreased evaporation of ground water into the air the climate becomes more variable.

In the belief of many engineers, the cutting off of forests has mechanical effect which may or may not be noticeably adverse. But most of us fail to recognize that each tree is in effect a biological pump, which in Nature's program seems to determine the general climate by "conditioning" the atmosphere out of doors, just as the modern ventilation engineer seeks to "condition" the air within buildings. A moderately sized tree pumps up from below as much as 30 to 40 gallons of water in twenty-four hours, and much of this by evaporation is "sponged" into the atmosphere; whence this water is precipitated as dew, rain or snow if and when the air cools.

In the presence of sunlight some of the water thus pumped up by the tree is borrowed by it for use for purposes of building up more material which is known as "growth." In case of certain plants this growth is possible only if this material is supplemented by species of microorganism or fungi which, in the presence of water, are necessary in preparing the material upon which rhododendron, laurel, huckleberries and some other species depend for food.

The methods of biologic utilization of impounded run-off water include as well the capture of silt and organic debris for corporation into farm land along the lines now followed in Egypt, France, Germany and other countries. This method can be applied profitably in many large areas in North America. The result will be to substitute one or more crops of protein foods, such as fishes, frogs, wild ducks, muskrats, etc., for rotation with cotton, cereals and garden crops. In addition, an important biological result of such rotation will be the control of such expensive farm pests as cut-worms, army worms, grasshoppers, mosquitoes, midges, etc., which will become food for the fishes and wildfowl.

This plan will provide a new method on a large scale of employing labor and capital in a new type of self-liquidating improvements, which in due time will improve the farmers and the nation, increase the opportunities for sale of healthful recreation to the public, and provide the normally sound method of increasing the water resources of the soil, regulate the atmospheric moisture and stabilize the rainfall, and check the recurrent floods and droughts.

Time does not here permit me to describe in detail how the conservation of run-off water will also tend to preserve the cycle of matter along our coastal waters, so essential to the supply of seafoods, which can be produced nowhere else and which are so necessary to health, since they provide iodine, copper, iron, magnesium, lime and other chemicals necessary for the normal mind in a sound body. We should endeavor to provide prosperity upon a biologically sound policy, rather than one of mere local political policy, which by robbing Nature brings temporarily wealth to a few men but leaves the world poorer through an illusive and delusive "prosperity."

Discussion

MR. FOLLETT (Michigan): I have been tremendously interested in this address by Dr. Field. I wish it could go into every paper in the United States and Canada. It is information that the public needs, and we cannot get very far without public support. I am sure you all realize that if the water table keeps on receding there will be very serious results affecting the productivity of the soil. The water table is not sustained by the current rainfall; it is a storage reservoir, an accumulation of rainfall and snowfall for generations. That water table, especially in the settled sections of the

United States, is being reduced at an alarming rate. You cannot raise crops without moisture. It is just as essential as fertilizer.

A little while ago I asked you to visualize the natural condition of the salmon streams a century ago before the water table had begun to recede. At that time there was a large run-off right near the surface of the earth, just under the forest floor. That condition has been destroyed by the wasteful destruction of the forests, yet conservation work was begun in Germany before we commenced our work of destruction.

DR. FIELD: May I point out that the U. S. Weather Bureau frequently forecasts showers in the neighborhood of Buckeye lake, which is about seven miles long and half a mile or so wide (Muskingum, Ohio, watershed). Five miles from that lake there may be no rainfall, indicating the local value of lakes and small streams. The annual record of rainy days here averages 140 for the past twenty-eight years compared with seventy-nine in another part of the same district but not so near to the lake. Every farm could develop a small pond—not a thirty-thousand acre pond—but if you have thirty thousand one acre ponds the effect will be equally good.

We are losing enormously from the silting of our rivers, caused by erosion resulting from the speed of run-off water. One of the functions of these ponds is to check the speed of the water through the treatment of small streams by check dams; the water slows up and gets another start; and before it gets going too fast it is checked again. It is exactly the same principle as that which they use in Egypt, except that the water from our run-off is not as full of humus as is the Nile water.

NATIVE GAME FISH IN MANITOBA

ALEXANDER BAJKOV

Biological Board of Canada

About ten years ago Professor A. G. Huntsman said that no part of our country is more poorly supplied with fish than is the prairie country, which is most distant from the sea coast, and at the same time poorly provided with large deep lakes. A small amount of moisture precipitated in most of the prairie country has caused a dearth of large bodies of water and is also responsible for the production of bodies of salt or alkaline water. Especially in dry years when the evaporation is much in excess of the precipitation, the level of the lakes rapidly goes down, and the water becomes more and more alkaline. Many species of fish perish and there seems no hope to restock many of these lakes again with game fish.

The future of these lakes is "Wheatfields," and nobody can help it. All this great wheat country only a few thousand years ago was covered by the largest fresh water lake in the world, populated by a tremendous amount of sturgeon, lake trout, whitefish, goldeye and other valuable fishes. Now the times are changed. Only pike, pickerel and suckers are to be found in some of these lakes. This is true of the southern portion of Manitoba and about the same condition is found in southern Saskatchewan, Alberta and in North Dakota.

It is fortunate that such a fish desert covers only one-third of Manitoba. In the coniferous forest area, north or east of Winnipeg, are splendid game fishes, and still better fishing can be found in the tundra areas on the Manitoban sea coast by anyone who will take with him a good mosquito-proof tent and an assortment of artificial flies. There is no wheat, except that in Churchill elevator, but a tremendous amount of arctic grayling and trout in the rivers.

Let us go east to the Ontario boundary—there is more water here than land. There, on the southwestern border of the granite Laurentian plateau which extends to Labrador, with the exception of only a few species, we can catch nearly all the fishes which are to be found in Ontario. There are many deep lakes; some of them are more than a hundred meters (—337 feet) deep, full of lake trout (*Cristivomer namaycush*), which provide good trolling in the summer and the fall and good spinner-fishing in the spring.

The rivers are clear and rapid, with many picturesque waterfalls, where probably the largest Canadian pike (*Esox lucius,* called locally a "Jackfish") can be easily caught. Under one waterfall on the Whiteshell river, a left tributary of the Winnipeg river, I caught three pike in only three casts, one after another, which were 30, 25,

and 19 pounds in weight, respectively. Pickerel also are extremely plentiful.

Such places are common as you proceed north along the eastern shore of Lake Winnipeg. In addition to a few large sturgeon, catfish, and some bass, which can be caught occasionally, there is found a real game fish, the mooneye (*Hiodon tergisus*), which can be caught with dry or wet fly. It is common in all the eastern tributaries of Lake Winnipeg but does not extend further north. An examination of the stomach content of the mooneye indicates that its main food during the most of the summer months consists of imago and subimago of certain species of *Ephemeridae* and other aquatic insects.

I tried, just for fun, dry-fly fishing. The result was amazing! These fish bite like rainbow trout. They are also as good fighters, due to the deepness of their body. The meat is splendid. In some places, namely in Pigeon river, which is probably the most beautiful river in Manitoba, during the month of August one can catch easily two or three mooneyes in one cast, using two or three flies on the leader. These fish keep together in schools in rapids where they hunt for aquatic insects. Ordinary trout flies as Royal Coachman, Professor, Silver Doctor, Olive Dun, March Brown, Blue Heron, Grey Hackle, Queen of Waters, etc., are very good for the mooneye. Another closely related species, the goldeye (*Hiodon chrysopsis*) can also be caught at this time, but strictly speaking this is a lacustrine fish, which occurs in the river rather occasionally.

Two or three species of Lake Winnipeg Tullibees should take the fly, since their stomachs sometimes contain insects that fly near the surface, but I have never heard of anyone catching one and personally I have not as yet tried them with artificial flies.

Few Canadian or American sportsmen know that the northern or "maritime" portion of Manitoba offers the angler some of the finest grayling fishing in the world. The Arctic grayling (*Thymallus signifer*) is extremely abundant in certain rivers in the vicinity of Churchill and reaches a very good size. There are only eight different species of grayling widely distributed throughout the northern portion of Europe, Asia and America. Many American and European sportsmen consider that grayling fishing with the dry-fly is very much better sport than trout fishing. The author, who has fished with artificial fly for all the species of grayling in the northern hemisphere, has concluded from his own experience that the species in question, as far as dry-fly fishing is concerned, is one of the best game fish in the world.

As practically no body of Canadian or American sportsmen are acquainted with this fish, let us introduce it to them: This species was first described by John Richardson, the naturalist and surgeon of the Franklin expedition of 1836, in Arctic America between Mackenzie river and Wellcome at the 62nd parallel northern latitude. Richardson named it *Thymallus signifer* after the highly appro-

priate Esquimo name (Hewlook-powak) denoting "wing-like fin," an allusion to its magnificent dorsal fin. The English name of this grayling in Richardson's book is given as Back's grayling, after the lost member of Franklin's Expedition, Captain Back, then a midshipman, who took the first specimen of this fish with artificial fly in about the year 1820.

No other fresh water fish has such beautiful coloration as this grayling. It is generally very dark. The back is nearly black, sides of a hue intermediate between lavender purple and bluish gray, with goldish-violet fluorescence. A few ⋁ and ⋀ shaped black spots are present on the front part of the body. The belly is white with two long dark brown stripes between the pectoral and ventral fins. The head is dark brown above, and the cheeks and gill-covers have a violet and golden irridescence. Jaws and snout are black, which is especially noticeable when the white mouth of the fish is open. All the fins are dark gray. The dorsal fin is magnificent. It is blackish-gray with lighter blotches and is covered by numerous beautiful round and oval blue spots. Its sharp end is edged with light red. The meat of this fish has a delicious flavor. Graylings run as high as four pounds in weight.

The best time for grayling fishing in Northern Manitoba is probably at the end of August and the beginning of September, when the flies are not so bad, the water is clear and warm weather usually occurs. The best artificial flies for this purpose have been found to be of medium size, brown, black or white (Silver Doctor, Palmer, Mayfly, etc.). The fish is so abundant and so tame that it is hardly necessary for the angler to be so quiet and well-concealed as when fishing for grayling in other countries.

The sport is excellent, for this fish often springs several feet out of the water with the fins erect when first struck. It tugs the line so strongly that it requires as much dexterity to land it safely as would secure a trout of several times its size.

The best time of the day for fishing grayling is about sunset, but it frequently takes a fly ravenously all day, especially during dull weather. The graylings concentrate mostly in the rapid parts of the streams, keep in large schools, and during the evening are continuously leaping from the water.

The grayling is very abundant in Deer river, a lower tributary of the Churchill river. It is also found in the other tributaries of the Churchill river and in the main river itself, several miles from the mouth, above the reach of the tide. Within a few hours about forty fish, weighing in all nearly a hundred pounds, were taken.

Another splendid gamefish, the speckled trout (*Salvelinus fontinalis*), is common in the lower portion of Nelson river and in its tributaries. It may be caught in quantity by means of the artificial fly or the spoon.

TAGGED SMALLMOUTH BLACK BASS IN LAKE ONTARIO, N. Y.

J. P. SNYDER

U. S. Bureau of Fisheries, Cape Vincent, N. Y.

Late in the fall of 1930 we completed four bass ponds at the Cape Vincent station, New York. Each of these ponds has an area of about three-fourths acre. In the spring of 1931, under permit from the state conservation department, we secured 500 adult bass from commercial fishermen fishing between Fox island and the mainland at the eastern end of Lake Ontario, about eight miles from Cape Vincent. These were placed in our ponds to propagate and later, early in July, they were taken from the ponds and returned to the lake. Prior to releasing them we tagged 150 of them. In this we used the usual aluminum numbered tags.

The tags were fastened to the upper, thick portion of the gill cover of the bass. During the summer and fall of 1931 twelve of these bass were taken and reported by hook-and-line men. Early this summer seven more of these fish were taken by fishermen and reported to us, but in each case the men reportd that the tags were simply hanging by the outer fringe of the gill cover. Since no more of these fish have been reported to us since early in July it is believed all or nearly all of them have lost the tags. I might say here that a few years ago we tagged several hundred brook trout, ranging from six inches to nine inches long. We then put them back into a gravel pond and left them there for one month to see what would happen. Apparently not a single fish was injured by the tags but by the end of one month forty per cent of them had lost the tags.

None of the nineteen bass reported to us as bearing tags were captured more than three miles from where they were originally taken from the nets of the fishermen and where they were released after being tagged.

Last spring again we secured 500 adult bass for our ponds. This time 350 of them were obtained from nets set in the same area between Fox island and the mainland and 150 were obtained from nets set in Chaumont bay, an arm of Lake Ontario. Unfortunately these bass from two different places when placed in the ponds were not kept in separate ponds. When they were released early in July 350 of them were tagged and released in the same area betwn Fox island and the mainland and 150 bearing no tags were taken back to Chaumont bay. Undoubtedly when we released the 350 tagged bass between Fox island and the mainland there were among them some of the bass originally taken from Chaumont bay. Since then a total of twenty-two of these tagged bass have been taken and reported to

us by hook-and-line men, but in this case five bass had migrated from five to nine miles from where they had been released. The question immediately arises were these five bass originally taken from Chaumont bay and if so were they hunting their way back home. If this is true then one of them did find his way back home, for one tagged bass was taken in Chaumont bay in the same area from which we had obtained 150 bass.

Those of us living at Cape Vincent at the eastern end of the lake had long believed there were marked migrations of bass, governed either by season, temperature or food, but in looking at the chart I have prepared there is nothing to indicate any marked or definite migration of these fish. None of the bass that were recaptured showed any bad effects from being transferred from the lake to our ponds and later being transferred from the ponds back to the lake or from the tags placed upon them, and not a single dead bass bearing a tag has been found by anyone.

It is known, however, that eight or ten bass in addition to those mentioned in this paper were taken by hook-and-line fishermen but we were unable to get the tag numbers, the names and addresses of the men, although in some cases we did hear where they had been caught. Doubtless still other tagged fish were caught by parties who failed to note the presence of the tags or who failed to report the tags to any one sufficiently interested to tell us of it.

Discussion

DR. DAVIS (Washington, D. C.): How were the tags attached, Mr. Snyder?

MR. SNYDER: The tags were placed on the gill cover of the trout, which were placed back in the gravel bottom pond. We do not know just how they lost those tags, but the trout sometimes have a tendency to try to rub themselves quickly against the bottom. It was our purpose to put six or seven hundred of these fish out in streams, but when we found that 40% of them had lost their tags in one month in the pond we abandoned the idea.

MR. LECOMPTE (Maryland): Have you a record of the distance they travelled after tagging?

MR. SNYDER: Yes, the percentage that did not migrate over three miles is shown on the map.

MR. LECOMPTE: Striped bass which were tagged at Annapolis, Maryland, were caught at four o'clock in the afternoon of the next day thirty miles up in the bay. Every tag returned has been from that section.

MR. MARKUS (New York): I have a paper ready for publication which deals with this subject. Instead of using trout I used common commercial and game fish of the Mississippi river, and the results obtained by Mr. Snyder seem to conform to the data that I have.

THE BREEDING HABITS OF THE BLACK-HEADED MINNOW (*PIMEPHALES PROMELAS* RAF.)[1]

V. C. WYNNE-EDWARDS

McGill University, Montreal

During the last two years, in the course of fisheries survey work conducted by the Quebec Provincial Government, I have taken specimens of the black-headed minnow in two lakes only out of several scores visited, both in the Laurentian mountains of Terrebonne county. It has been collected also in the neighboring county of Argenteuil, but not as yet in the province south of the St. Lawrence river. It occurs in the Lake Champlain watershed across the International Boundary.[2] The two lakes mentioned are both small and both perched on the tops of hills considerably above the general elevation, about thirty miles apart.

Specimens were first obtained on June 19th, 1931, and the males at that time had the rugose skin between the back of the head and the dorsal fin fully developed. This is striking in appearance; it is due to a thickening of the epidermis overlying the scales. It is not described by Jordan and Evermann[3] or by Forbes in "The Fishes of Illinois"[4]; the colored plate in the latter work does not show it, and the specimen illustrated in the New York State Report (1928) is a female. Figure 1 is taken from a male in my collection of June 19th, 62 mm. in length, and showing the pad at its maximum development. It will be observed that the normal outline of this part of the body is considerably modified, a pronounced nuchal groove being formed between the head and the swollen skin. The latter is of a bluish or glaucous color in preserved specimens.

At the time I wondered what the function of this structure might be. It is a secondary sexual character, but has not the appearance of an adornment, and is therefore presumably of some use in reproduction.

On July 17th, 1931, I found this species for a second time. The place was a small shallow lake on one of the hills at St. Margaret's. Near the outlet the water is scarcely two feet deep, with a mud bottom and a dense growth of yellow water-lilies (*Nuphar advena*). On the underside of many of the lily-pads was a layer of eggs, and it was a matter of a few moments to discover the male black-headed minnows which guarded them. These by now showed a brownish-

[1]When this article was written I had not seen the valuable paper by R. F. Lord (Trans. A. F. S., 1927, pp. 92-99) on this species. The present observations of the fish under natural conditions may, however, supplement the extensive data there.

[2]N. Y. State Conservation Dept., Report No. 19 (1928), 1929.

[3]*The Fishes of North and Middle America.* 4 vols., Washington, 1896-1900.

[4]2nd Edition, 1920. Plate facing p. 128.

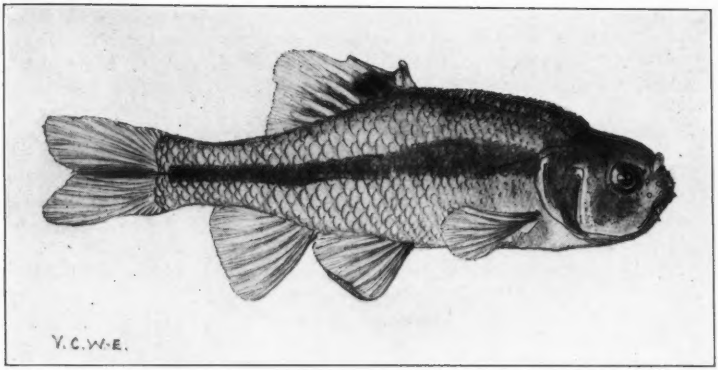

FIGURE 1. *Pimephales promelas* Rafinesque, from a male 62 mm. in length, collected at St. Jovite, P. Q., 19 June, 1931.

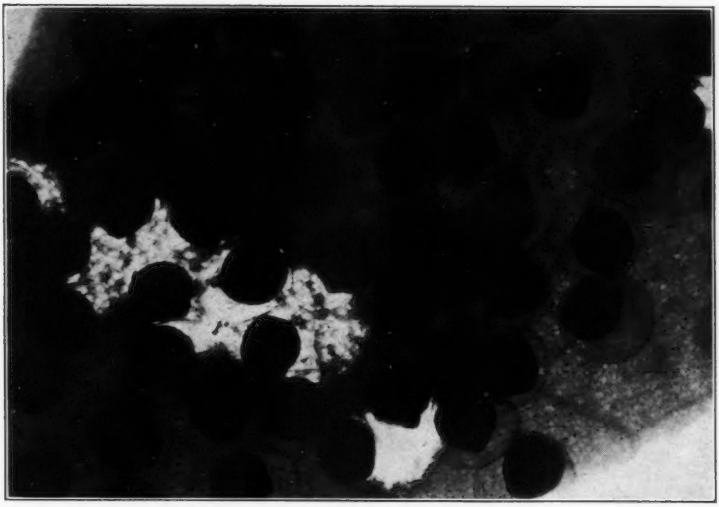

FIGURE 2. Eggs of *P. promelas* attached to the lower surface of a water-lily pad (from preserved material).

UNIV. OF MICH.

red color on their sides. They were very pugnacious, attacking intruding males with great speed and vigor. No sign of any female was to be seen—evidently the whole care of the eggs is in the hands of the male.

I spent some two hours watching the behavior of these fish, three or four of which were in view from time to time as they passed under the lily-pads. When all the disturbance had died down, it became clear that their task was not one of idle watching; they were perpetually on the move, apparently striking the lily-pads from below and then dropping back to do the same again. It was possible to see the effect of this on the upper side of the leaf: the impact, though gentle, was strong enough to raise it appreciably. The leaves attended in this way were marked down, and each one had eggs attached to the lower surface; none of the unused leaves was touched.

By good fortune I was able to see a male whose "nest" was so close to the edge of a leaf that I could watch him at work. He swam up and struck the leaf a glancing blow, *stroking the egg-layer with his dorsal pad*. The use of this strange appendage was thus discovered.

It is more difficult to account for the performance. The eggs are attached in a single layer as a rule; here and there there are small areas two layers thick. They adhere to the leaf and one to another (Fig. 2) by a viscous substance which coats the egg-membrane. They are not, however, stuck fast, but can be moved about without becoming detached. The action of the male fish almost certainly results in turning them over and over, perhaps to permit a free access of oxygen to all sides, which may well be necessary for eggs spawned in stagnant muddy water. The eggs are 1.30 mm. in diameter, with a very large perivitalline space; the actual yolk-sac is only 0.8 mm. in diameter and moves freely within the egg-membrane.

It appears that the eggs are laid in fairly small numbers at a time for a considerable period; on a pad which I collected there were eggs at all stages from the earliest to those containing embryos which hatched on being preserved. The rate of development would, of course, be very rapid, owing to the high temperature of this particular habitat. The length of the newly-hatched larva is 4.8 mm. Possibly the actions of the male assist in breaking the egg-membrane also.

Other secondary sexual characters observed are the tubercles on the snout (16-22 on the upper side, 4-6 on the lower), presumably offensive weapons; an enlargement of the pelvic fins, perhaps of service in the act of fertilization; and the epigamic coloring of the ventral part of the body.

THE LAW OF FISH AND FISHING IN THE PROVINCE OF QUEBEC

A. M. WATT

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Two questions involving the law are often asked by fishermen: Who owns the fishes anyway? and, Where and under what conditions may I fish? These two questions indicate the fundamental distinction underlying the law; that is, the distinction between the ownership of fishes and the ownership of a right of fishing.

The first question admits of a very simple answer: Nobody owns fishes in their wild state. Our Civil Code says: "There are things which have no owner, the use of which is common to all," and another provision adds that, "Things which have no owner are held to belong to the Crown." The sense in which fishes are "held to belong to the Crown" is indicated by a further article stating that "The right of hunting and fishing is governed by particular laws of public policy, subject to the legally acquired rights of individuals." What all this really means is that fishes in their wild state belong to the public at large, for whom the Crown acts as a sort of trustee by regulating their exploitation.

To say that fishes belong to the public at large is the same as saying that they belong to no one in particular. Individuals may, however, acquire ownership in them by merely taking possession. An exception to the rule that the ownership of fishes is acquired by the first possessor has been created by Section 13 of the Quebec Fisheries Act, which provides that anyone fishing without permission in leased waters shall not acquire title to the fishes so caught, which shall become the absolute property of the lessee.

This mention of fishing leases introduces the second question as to the right to fish. Normally the exclusive right to fish in any waters is an incident of their ownership, or, more correctly, of the ownership of the land beneath the water. A preliminary distinction must be made at this point; that is the distinction between navigable and floatable rivers and lakes and those which are non-navigable and non-floatable. The former with their banks are considered to be dependencies of the Crown domain, while the latter belong to the riparian owners on either side to the middle of the stream or lake. This distinction, while most important and the subject of many judicial decisions, does not apply to lands granted by the Crown after February 9th, 1918. An amendment to the Civil Code, passed in that year, applies the rule of navigable and floatable river to all water bordering on such grants—they remain dependencies of the Crown domain.

In still another manner the Crown has retained ownership of non-navigable rivers and lakes. The Quebec Fisheries Act, Sec. 7, provides that: "Sales and free grants of lands belonging to the Crown are and have been since the 1st June, 1884, subject to a reserve, *in full ownership by the Crown*, of three chains in depth of the lands bordering on non-navigable rivers and lakes in the Province."

The waters of the Province may be divided into three classes:

1. Waters forming part of the Crown domain, including all navigable and floatable rivers and lakes, and all waters bordering on lands granted since February 9th, 1918.
2. Waters of which the Crown has remained the riparian owner either by original title or by reason of the three chain reserve.
3. Waters, always non-navigable and non-floatable, belonging to private individuals as the riparian owners.

In the first two classes of waters everyone has the rights to fish, subject, of course, to the rules laid down by the legislature. In the third class of waters the exclusive right of fishing belongs to the riparian owners, who may legally prevent anyone from trespassing.

Although the right to fish is usually a corollary of the ownership of land, this is not always so. The two rights may become separated. Thus, the owner, be he a private individual or the Crown, may convey the right of fishing to another. This leasing of fishing rights has become in recent years a common practice with the Crown, 3,938 lakes and 321 rivers being under lease in 1930. Properly speaking these are not leases at all. They do not convey to the lessees the right to fish. *That*, they already possessed. What the so-called lease does is to deprive all but the lessee of the right to fish by making his right exclusive. The same with private individuals. The lessor does not lease anything. All he does is to agree, for a consideration, not to consider the lessee as a trespasser when he enters on the lessor's property for fishing purposes.

To sum up, the ordinary citizen may exercise his right to fish in all the waters of the Province except:

1. **Those the exclusive right of fishing in which has been leased by the Crown to certain persons.**
2. **Those in which the exclusive right to fish belongs to a riparian owner other than the Crown.**

The right to fish, wherever it exists, is subject to the general laws of the Province regulating its exercise, and covering such matters as closed seasons and the sort of tackle to be used. No person domiciled in the Province requires a license to fish; others must procure a license.

SUGGESTED METHOD OF PASSING FISH OVER HIGH DAMS

C. W. HARRISON

Supervisor of Fish Culture, British Columbia

I have the honor to present herewith a plan of a fishway showing the writer's conception of a structure that might be given consideration in connection with the problem of the passage of fish over high dams on waterways frequented by anadromous fish.

The special features the writer has attempted to illustrate are: an arresting dam of sufficient height to guard against the passage of fish past the entrance to fishway and protect them against the tremendous force of the discharge from the penstock, also for the purpose of arresting and evenly distributing that discharge to the river again, thus giving the fish uniform water flow during their passage up stream and when nearing the entrance to the fishway. With a more or less uniform flow of water over the full length of the arresting dam, when the fish arrive at this obstacle they will pass along it until they find the entrance to the fishway.

With regard to the fishway itself, and to suit different conditions, it can be constructed in either a straight line, curves or angles to shorten or lengthen it to suit the distance between the arresting and main dam. It has been suggested that the arresting dam would be detrimental to the hydraulic head required. In this connection I may say that usually streams on which such installations are introduced have a very pronounced gradient and, supposing the position of the ten foot arresting dam was one thousand feet below the main dam, a one per cent grade would back the water barely to the extreme foot of the main dam. To further reduce that detrimental feature, I would suggest that consideration be given to a six or eight foot cement arresting dam surmounted by an iron bar screen, this guard to be slightly curved towards down stream, which would give a lesser obstacle to the hydraulic head and still maintain the principle of arresting the passage of the fish past that point and distribute evenly the discharge from the penstock to the river below.

When conditions necessitate the outlet from the penstock can be a greater distance below the main dam than shown in the plan herewith. Either the fishway can be extended all the way to the arresting dam, thus reducing the rise at each pool, or a raceway of any length may be installed to guide the fish to the foot of the fishway.

Another special feature shown on this plan is the high and low water level control at the head of the fishway. At low water the fish climb the fishway until they reach the topmost step, then swim directly into the lake through a raceway. The length of this raceway is dependent on the difference between high and low water

levels. For example, if the extreme high water level is ten feet above extreme low water level and a two foot raise at each pool is required, it would be necessary to install four control gates. As each gate was raised, another pool 10′ by 10′ would be provided, and no matter what the water level in the lake, only the proper quantity would pass down the fishway. Suitable hoisting mechanical power can be installed, and as the primary purpose of high dams is to provide electrical power, a system of automatic control of the gates can be worked by motors with thermostatic control; thus, at any height of water, the particular gate requiring adjustment would be either raised or lowered automatically.

Another objection that might be cited is the cost of such an installation. Naturally an installation of such magnitude would entail heavy expenditure, but to offset an obstacle such as a one to two hundred foot dam and install any construction that would enable fish to pass would undoubtedly be a costly undertaking. For example, and taking into consideration the annual commercial value of sockeye salmon that return each year to the Nimpkish lake district, British Columbia, and the fact that under proper protection this run will continue for all time, even if the cost of protective measures was 50% of the cost of the power project, it would be money well spent.

So far as the writer is aware, no successful mechanical methods of lifting fish over high dams has yet been devised, and some time ago, when the Nimpkish lake dam project was discussed, it was suggested that artificial propagation might take care of the situation. In the writer's opinion the success of such measures would be extremely doubtful and would be very costly, both for original establishment of station, equipment and annual maintenance.

Another condition for which provision must be made is the safe passage of fish down stream, and in the case of anadromous fish, the migration consists of fingerlings under one year of age and yearlings. The Pacific coast salmon fingerlings and yearlings swim near the surface when passing down stream to the sea, and I am informed that the suction at the surface to the intake of the penstock in most cases is not very pronounced, therefore, would not affect the passage of small fish to any great extent. The primary object is to store water, and, I believe that only in seasons of heavy precipitation does water pass through the head gates of high dams. In that case, it is assumed that the small fish would find the fishway and pass safely down stream. At the time of migration, should there be an overflow over the dam, consideration must be given to protection measures to obviate injury or death of the fish when falling from such a height. In this connection, the writer believes that if the face of the dam has a very decided curve and a reception pool is provided at the foot, and the dam faced with smooth cement, commonly termed "glass faced," the fish will not suffer injury.

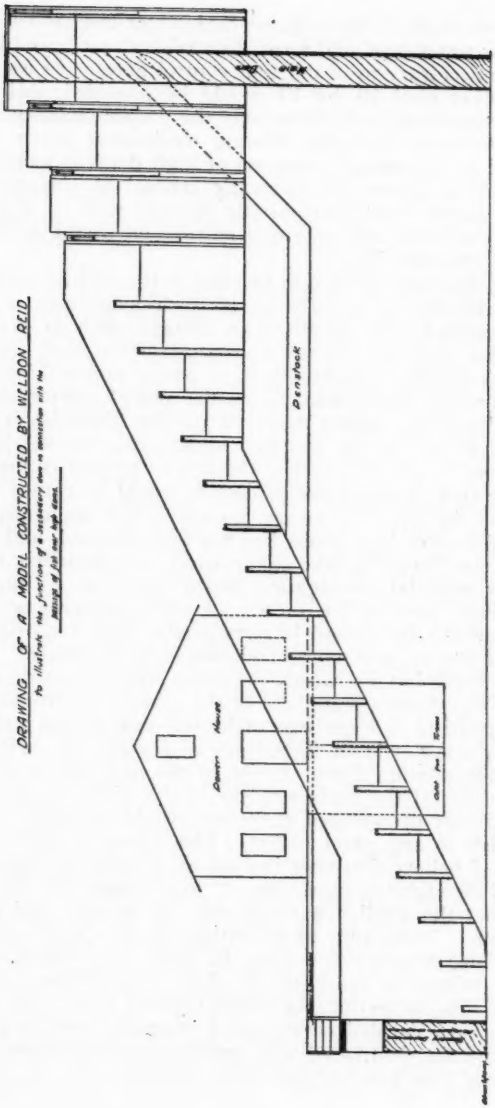
DRAWING OF A MODEL CONSTRUCTED BY WELDON REID
To illustrate the function of a secondary dam in connection with the passage of fish over high dams.
Power House
Penstock
Dam
Flume

Illustration showing location of secondary dam to guide fish to fishway.

APPENDIX

APPENDIX

ABSTRACTS OF FOREIGN FISHERY LITERATURE

The publication of these abstracts in the Transactions is an innovation which it is hoped will prove of value to members of the Society. There is a quite extensive foreign literature dealing with fish culture and its attendant problems which is for the most part inaccessible to our fish culturists, and it is the purpose of these abstracts to acquaint members of the Society with recent progress in this field.

In view of the limited funds available for this purpose it was felt that it would be better to prepare fairly complete abstracts of some of the more outstanding publications which have appeared in the last year or two than to attempt a complete list of publications in foreign languages dealing with fishery problems. Such a list would permit of only very short abstracts and consequently would be of relatively little value except to those who have access to foreign periodicals.

The following abstracts have been prepared by Dr. N. A. Borodin, Curator of Fishes, Museum of Comparative Zoology, Cambridge, Mass.

Allgemeine Fischerei Zeitung, Vols. 1931 and 1932, Augsburg, Germany (*General Fishery Gazette*).

This journal, published fortnightly, is the oldest German magazine devoted to fisheries and fish culture, being now in its 57th year. It has always been closely connected with the Bavarian Fishery Society and at the present time is the official organ of the German Fishery Society. In the pages of this magazine have appeared many articles by the leading German specialists in fish culture, including the late Dr. B. Hofer, Dr. Schiemenz, Dr. E. Walter and others.

In the volume for 1931 we find an important paper on experiments with trout made at the Pertelnicken pond culture station of the Konigsberg University Fishery Institute by Dr. U. Sklower. The purpose of these experiments was to determine how to produce the best trout fingerlings by artificial methods. As a result of the experiments the author gives the following practical advice to fish culturists:

In order to obtain the greatest possible growth it is necessary that the young trout be not too crowded in the hatchery troughs so that each individual fish has enough space to move freely. It is also important to aerate the water supplied to the troughs. Daylight must not be admitted to the troughs until the eggs have hatched; after that the troughs with fry must be kept uncovered. The question of space is also an important factor in the rearing pools since the fingerlings must not be crowded in any way.

By feeding the fingerlings with calf's thyroid glands stronger fingerlings

can be reared than by feeding with spleen. Young female trout produce smaller eggs than older fish. The young hatched from the smaller eggs remain smaller up to the end of their first year than those hatched from larger eggs. The common practice at the present time of avoiding the use of old females for brood fish must be recognized as harmful to the production of the best fingerlings for planting since larger fish for future generations will be produced from seven to eight-year-old females than from those only three to four years old.

Dr. Lubbert contributes an interesting and well illustrated paper on a new installation for catching eel-fry and distributing them. He gives a description of a dam with barrage at Epney, Great Britain, where young eels ascending the Severn river are collected and the installation for packing young eels at Hamburg, built in 1929-30. The paper concludes with statistics of the number of eels received by Germany during the past twelve years. A total of 71,000,000 were imported during this period at the rate of five to nine million annually. This gives some idea of the scale on which eels are planted in the marshy ponds of this country.

Another valuable paper by Dr. Metzner and Dr. Rohler gives the results of new investigations on the chemical composition and on the relative amounts of edible matter and offal of freshwater fish. The figures and graphs which accompany the paper show that the freshwater fishes contain from 55% to 66% of edible matter and 33% to 44% offal. The edible portion of the fish contains from 26% to 77% of fat and 12.22% to 18.15% protein. The trout has the highest percentage of protein, the eel the highest percentage of fat, and the pike the lowest percentage of fat. A comparison of the flesh of freshwater fish with that of some marine fishes and meat is given in one of the graphs.

Bulletin Francais de Pisciculture, 1932. (*French*)

Numbers 51 and 53 of this journal contain a critical review by M. Vouga, Inspector of Fisheries at Neuchtel (Switzerland) of the methods of artificial fertilization used in fish culture. The author states that the old wet method of fertilizing eggs in water has now been entirely abandoned because many eggs treated in this way remain unfertilized. This is due to the fact that in water the membrane of the egg becomes distended and the micropyle through which the spermatozoon enters the egg is closed so that fertilization cannot take place. On the other hand the spermatozoa are unable to live in water more than one minute. In most countries at the present time fish culturists are using the Russian or dry method of fertilization introduced by V. Vrassky. The author then gives a description of this method which is well known to American fish culturists. The dry method usually gives excellent results and ordinarily over 90% of the eggs are fertilized. Sometimes, however, this method has resulted in partial failure, especially in the case of rainbow trout reared in artificial pools.

The old wet method has the advantage of resembling more nearly the natural fertilization of eggs which are spawned by the female into the

water. At the moment of coming into contact with the water the eggs imbibe water by osmosis while the spermatozoa enter and complete the process of fertilization. This is exactly what happens under natural conditions. The female swims close to the bottom with the male close behind. Suddenly the female turns on one side and drops several eggs; the male immediately extrudes several drops of milt, which, carried by the current, accompanies the eggs rolling at the bottom and during these few seconds the fertilization takes place. If the sperm does not enter the egg immediately fertilization will not take place even when there is an abundance of milt.

In the new Swiss or extra dry process the female is wiped dry with a towel. The hands are also kept dry so that no water reaches the eggs, which are collected from several females in a pan with perforated bottom. A male is then wiped in the same way and the milt squeezed onto the eggs. This operation is repeated with a second and third male. The eggs and milt are then mixed with a goose feather and placed without a drop of water in a glass jar. If the eggs are to be transported some distance to a hatchery the jar is put in a case with cover. When delivered at the hatchery the contents are poured into a hatching jar or placed on trays and a current of water turned on. In so doing one copies the natural process where the eggs are put into the water and not the water poured on the eggs.

According to the author, this modified dry method gives better results than the old dry or Russian method, especially if it is used with sticky eggs like those of pike. Instead of 50% of fertilized eggs from 95% to 98% are fertilized by this method. The use of the Swiss method also tends to prevent the eggs sticking to one another, which greatly facilitates the handling of the fertilized eggs. Whether the spermatozoa enter the eggs when they are still dry or whether this occurs later when the eggs are placed in water has not been determined. The author, however, expresses the opinion that the spermatozoa which are so sensitive to the injurious effects of water might be able to live much longer when mixed with the mucus of the eggs and consequently be able to fertilize the eggs after several hours of transportation.

Experiments with eggs of whitefish (*Coregonus exiguus*) gave excellent results a fertilization of 97% being obtained when the eggs were taken near the hatchery, and 80% when the eggs were delivered after nine hours of transportation. A slightly modified method was successfully used in the fertilization of trout eggs collected at some distance from the hatchery. The eggs, while still dry, were placed in a handkerchief without mixing with milt, which was added at the hatchery, where they arrived 7-8 hours later.

The last part of M. Vouga's paper is devoted to some "tricks of the trade" elaborated in Switzerland by long experience. They use for fertilization eggs of lake-trout and white-fish caught by fishermen not more than two hours previously. Males of rainbow trout to be used for fertilizing eggs should be placed in inclosures above the females, not below,

in order to prevent them extruding their milt. The females should be fed until three hours before the eggs are to be taken. All males and females before being stripped must be put for five minutes in a bath of formalin (6-7 cc. of commercial 40% formaldehyde dissolved in 10 liters of water).

This practice, introduced by Prof. Leger, is considered an efficient means of protecting the eggs against the disease "costiasis." The flagellate protozoan *Costia necatrix*, the causative agent of the disease, can be present in numbers in the mucus on the fish and may be easily mixed with the eggs and milt. It is recommended at the same time to disinfect the towel, the hands of the operator and the net used for catching the fish. It is very important to strip the eggs from the females fully which can only be accomplished by stripping them several times. This will prevent any difficulty in getting eggs from the same females next year.

In numbers 48 to 51 of the same journal is an important paper by K. Berg of the Hydrological Laboratory of the University of Copenhagen on the group of crustaceans known as Cladocera which play such an important role in fish culture. This paper deals with the anatomy, taxonomy, method of reproduction, food and propagation of these crustaceans. It is well illustrated and written in a popular style.

Prof. Rossler, Director of the Institute of Applied Zoology at Zagreb, has an article on the "Exploitation of Ponds in Yugoslavia." There are in this country 200 fish ponds, with an area of 5,477 hectares, which produce annually from 17,750 to 22,500 quintals of fish, mostly carp. This gives an average yield of 325 to 400 kilograms per hectare. The climatic conditions are very favorable for carp culture and fish of commercial size can be reared in two years.

Bulletin of the Leningrad Institute of Ichthyology, Volume XII, Fasc. I. (*Russian*).

This work, which appeared in 1931, contains several articles of importance on the biology of Russian salmonid and coregonid fishes from Ladoga and Onega lakes and the Svir river. This river, 225 kilometers in length, connects the two lakes which are located in the northeastern part of Russia. A hydro-electric plant is to be built on the Svir river with a large dam, that will prevent the free passage of fish which live in Lake Ladoga and migrate up the river to spawn. For this reason a thorough investigation was made of the fishes of these lakes and the river connecting them. A number of scientists were employed in this investigation during 1927 and 1928. The first article gives a general report on the work and its results. It deals with the biology of the salmon, salmon-trout and whitefish and some other less important commercial fishes and with the local fish industry including its economics and technique.

A second paper deals with experiments in keeping the salmon in live cages for artificial propagation which proved very successful. The salmon (*Salmo salar relictus*), after being kept in live cages, gave ripe eggs which after being artificially fertilized gave normal fry. Thorough observations were made of the

runs of the salmon and salmon-trout (*Salmo trutta lacustris*) in order to determine the best location for the fishway over the dam and also the time during which the fishway could be closed without considerable damage to the migrating fish.

A third paper by the same author deals with the marking experiments on salmonid fishes. A total of 197 fish were marked in 1929 and 97 in 1931 with copper plates attached to the dorsal lobe of the caudal fin.

Although only 18 of these fish were recaptured the author concludes that the experiments showed that the salmon migrate up the Svir river for over 175 kilometers, and that the fish may cover as much as 8.5 kilometers in 24 hours. The author also concludes that the salmon trout prefer to turn into the tributaries while the salmon keep to the main river. No indication was found that the Ladoga salmon ever reach Onega lake. The most important time for the upstream migration is for salmon from the end of June to the middle of September and for salmon-trout the months of October and November.

Bulletin de la Societe Centrale d'Aquiculture et de Peche, 1931, Nos. 1-12, and 1932, Nos. 1-6, Paris, France. (*Bulletin of the Central Society of Aquiculture and Fisheries.*)

This journal, edited by Dr. J. Pellegrin, the well known ichthyologist, contains several papers of considerable interest. A. Gandolfi gives the results of his detailed measurements of young eels known in France and Spain under the names "Civelle" in the colorless stage before ossification of the skeleton and "Dibales" in the next greyish stage after ossification has begun. The author measured and weighed thousands of individuals of both sexes taken in different places and at different seasons in order to obtain a picture of the growth of young eels in freshwater, where they remain throughout most of their complicated life history.

A detailed statement of the post-larval development and growth of young eels under different conditions has a scientific as well as a practical value since the eel is a very important fish in the southern brackish waters of France, Spain and Italy. Many interior freshwater ponds of Germany are also regularly stocked with young eels, caught mostly near Epney on the Severn river in Great Britain and transported to German ports in great numbers. The extent of this industry is indicated by the fact that 3,870 pounds were imported in 1930. One pound contains about 2,000 young eels.

In Spain, Italy and France young eels are sold in quantities in the fish markets and being boneless they are highly esteemed by the whole population. The author states that at San Sebastian alone 245,195 kilograms of young eels were sold in 1928 and 154,782 kilograms in 1929.

Dr. Carie in a short article (No. 4-6, 1931, pp. 44-45) gives interesting information concerning the acclimatization of the cyprinodont fish, *Lebistes reticulatus* Peters, in the freshwaters of the Island of Mauritius. This fish was introduced from Barbados in 1908 for the purpose of destroying the malarial mosquito. According to the testimony of the fisheries inspector it has now be-

come a nuisance and has caused a noticeable decrease in the abundance of the valuable "Gourami" (*Osphromenus olfax*) and a commercial crustacean (Palaemon).

A short review of the papers read at the VII Congres d'Aquiculture et de Peche which met at Paris during the Colonial Exhibition of 1931, is given by Dr. Pellegrin. There were sections on scientific research of fresh waters, on fish culture, and on freshwater fisheries. The following papers may be mentioned as indicating the nature of the subjects discussed at these meetings: culture of eels in Germany by Dr. H. Lubbert; propagation of eels in the Mediterranean by M. L. Sanzo; development of fish culture in Switzerland by M. Surbeck; creation of a new race of carp in France by M. Gallois; the principles of rational carp culture by Prof. Spitchakoff; and fish culture as an important factor in the control of malaria by Dr. J. Legendre.

La pesca nei mari e nelle acque interne d'Italia. Ministero dell' Agricoltura e delle Foreste. 3 Volumes, Rome, 1931. (*Marine and Freshwater Fisheries of Italy. Ministry of Agriculture and Forestry.*)

This is a really capital work on Italian fisheries and fish culture published by the Ministry of Agriculture and Forestry. Volume I contains general information regarding the state and cooperative organizations dealing with different aspects of the fisheries, including scientific institutions, professional schools and societies devoted to the study and promotion of different branches of the fisheries and fish culture. This volume also includes sections on the manufacture of fishery products and the laws and regulations of the fisheries.

Three state fish cultural stations at Brescia, Belluno and Roma for the propagation of freshwater fishes (trout, whitefish and carp) are described and figured.

Volume II contains general information concerning the marine fisheries of Italy with a chapter on a peculiar kind of fishery in brackish lagoons, the outlets of which are barred by dams and weirs in the form of labyrinths. This particular kind of fishery called "Vallicultura," i. e., propagation of fish by erecting dams and fences, is very popular in Italy. It is conducted on a large scale and is of great importance. The oldest and best established are the fisheries in the lagoons of Comacchio, which are fed by a branch of the Po River. Eels, mullets and gobies from the Adriatic Sea enter the spacious lagoons or brackish lakes in immense numbers. Here owing to the rich supply of food they grow rapidly, and after one to three years start seaward when they are caught in the weirs. Besides Commacchio there are seven other places where the same system of fish culture is used and has proved to be very profitable. Excellent detailed maps accompany the description of the lagoon fisheries. The Italian "Vallicultura" should be of special interest to the fish commissions of the southern states, where quite similar conditions are found.

A section of Volume II is devoted to freshwater fisheries which are of much less importance than the marine fisheries. The development of the freshwater fisheries is closely connected with the very important problem of getting rid of the large numbers of marshes and swamps which are instrumental in the spread of malaria. The state is making strong efforts to reduce the area occupied by swamp lands through the construction of lakes and drainage canals. These are stocked with fish and particular attention is given to the propagation of Gambusia and other small fish which feed on mosquito larvae. The improvement of swamp lands has resulted in the introduction of rice culture and a system of irrigation. An experimental station has been established for the study of problems connected with rice culture, including the propagation of fish.

Volume III contains general information on the marketing of fish products in various provinces and municipalities. It also contains information regarding the fishery industries in the Italian colonies and short reports of the Italian representatives on the fishery industries of various foreign countries.

"Rybovodstvo" Fish Culture, Its Scientific Foundations and Practice, by O. A. Grim. (*Posthumous edition, State Agriculture Publishing Co., Moscow-Leningrad. 1931.*)

This textbook is notable for the fact that it contains all up to date scientific data on hydrobiology. Dr. Grim was for many years Inspector of Fisheries at the Department of Agriculture and Director of the state fish cultural establishment at Nikolsk.

In Chapter I the essentials of up-to-date scientific data on freshwater biology are presented in a popular but scientifically precise manner. This is followed by a brief account of the anatomy and physiology of fishes, special attention being given to propagation spawning, heredity and the formation of races.

Chapter III deals with artificial propagation, special attention being paid to methods of fertilizing and handling the eggs. This is followed by a chapter on fish culture in natural ponds and in lagoons or shallow brackish water bays.

Chapter V deals with pond culture and treats the subject very extensively and in detail, including construction of ponds, their management, and control of aquatic plants and the improvement of old ponds. This is followed by a short treatise on trout culture in creeks and artificial ponds. The following abstracts dealing with the care of trout in ponds may be of interest to American fish culturists:

The author prefers small ponds rather than the old-fashioned type of large ponds of 1-2 hectares. These are not convenient since they present difficulties in watching and feeding the fish. Each trout farm should have at least several ponds of different sizes. Fingerling trout need small elongated ponds, or channels with a gravel bottom and a strong current of cold water. Trees and bushes should be planted along the banks of the pools

for the propagation of insects which serve as food for the trout and also to protect the water from becoming too warm. The pools should be stocked at the rate of about 5 fingerlings per square meter. This is in case the natural food is sufficient, otherwise the fish must receive some artificial food in addition. Under favorable conditions with an abundance of food fingerlings may reach a length of 6½ cm. (2½ in.) by fall and in exceptional cases the length may reach 9 cm. Under favorable conditions about 70% of the fish will survive so that they must be transferred to larger ponds in the fall.

For adult trout of three years of age or older ponds of larger size up to one-half hectare in area can be used. For commercial purposes it is not profitable to keep the fish after the second year since older fish consume more food without a corresponding increase in growth.

The most difficult problem in trout culture is in connection with their food. It is not sufficient to choose a suitable food; it is also important that the fish be fed at a fixed time and in such amounts that they will have plenty to eat without overfeeding. Trout fry, according to the recommendation of the author, should be fed preferably with small living animals such as crustaceans (Daphnia, Cyclops, etc). These crustaceans can be collected from natural sources or can be reared artificially. For this purpose shallow ponds, concrete pools or large wooden tanks can be used. The author used tanks about 4 feet in diameter and 16 inches deep. These are fertilized with three shovels of bird's or fresh cow manure and then exposed to direct sunlight for several days, after which a bucket of water containing daphnia and other crustacea is poured into the tank. A temperature of about 12° C. and sunlight are needed for the successful propagation of crustacea.

When the fingerlings are large enough it is advisable to feed minnows. These may be introduced by putting algae or other water plants to which the eggs of minnows adhere into the ponds. The author admits that it is not an easy problem to provide a sufficient amount of live food and in many cases this must be supplemented by artificial food. Liver is recognized as being the best food for young trout and meat and fish for adults. The author recommends keeping a number of crawfish in trout pools to consume the surplus food.

The continuance of these abstracts will depend entirely upon the reaction of the members of the Society and the funds available.

Members of the Society are urged to prepare abstracts of important fish cultural or research findings which appear in foreign fisheries literature and send them to the Secretary for the consideration of the Committee on Publications. Credit will be given for all abstracts used. If unable to prepare abstracts, bring the publications to the attention of the Secretary.

AMERICAN FISHERIES SOCIETY

Organized 1870

Certificate of Incorporation

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

Seymour Bower	(Seal)	Theodore S. Palmer	(Seal)
Theodore Gill	(Seal)	Bertrand H. Roberts	(Seal)
William E. Meehan	(Seal)	Hugh M. Smith	(Seal)
		Richard Sylvester	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS
(As amended to date)

ARTICLE I
Name and Object

The name of this Society shall be American Fisheries Society. Its object shall be to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; the uniting and encouraging of all interests of fish culture and the fisheries, and the treatment of all questions regarding fish, of a scientific and economic character.

ARTICLE II
Membership

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society.

The annual dues of active members shall be three ($3.00) dollar per year, payable in advance. In case of non-payment of dues for two consecutive years, notice shall be given by the Treasurer in writing, and such member remaining delinquent after one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of two years, except upon payment of arrears.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries shall be admitted to membership upon application and the payment of one year's dues. The annual dues for libraries shall be three ($3.00) dollars per year.

State Memberships.—Any State, Provincial or Federal Department of the United States, Canada or Mexico may, upon application and the payment of one year's dues become a State member of this Society. The annual dues for State memberships shall be ten ($10.00) dollars per year.

Life Memberships.—Any person may, upon a two-thirds vote of the members present at any regular annual meeting and the payment of fifty ($50.00) dollars become a life member of this Society and shall thereafter be exempt from payment of annual dues. The Secretary and Treasurer of the Society are hereby authorized to transfer members from the active list to the list of life members provided that no member shall be so transferred unless he shall make request for such transfer and shall have paid dues as an active member of the Society for at least twenty-five years.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron of this Society with all the privileges of a life member, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President (by name) of the United States, the Governors (by name) of the several States and the Secretary of Commerce of the United States (by name) shall be honorary members of the Society.

Election of Members Between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized during the time intervening between annual meetings, to receive and act upon all applications for individual and club memberships. A majority of such committee shall decide upon the acceptance of such applications.

Voting.—Active members and life members only shall have the right to vote at regular or special meetings of the Society. Fifteen voting members shall constitute a quorum for the transaction of business.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a President and a Vice-President, who shall be ineligible for election to the same office until a year after the expiration of their term; a Secretary, a Treasurer, a Librarian, and an Executive Committee of seven, which, with the officers before named shall form a council and transact such business as may be necessary when the Society is not in session—four to constitute a quorum.

In addition to the officers above named there shall be elected annually five Vice-Presidents who shall be in charge of the following five divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the annual and all special

meetings of the Society, shall be ex-officio chairman of the Council of the Society, and shall exercise general supervision over the affairs of the Society.

The Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, attend to the publication and distribution of its Transactions, attend to its correspondence, promote its membership, and arrange for annual and special meetings.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of one thousand ($1,000) dollars to be approved by the Executive Committee and to be paid for by the Society.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions. Other officers shall perform such duties as shall be assigned them by the President.

ARTICLE V

Meetings

The regular meeting of the Society shall be held once a year, the time and place being decided upon at the previous meeting, or, in default of such action, by the Executive Committee.

ARTICLE VI

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Applications for memberships.
4. Reports of officers:
   a. President.
   b. Secretary.
   c. Treasurer.
   d. Vice-Presidents of Divisions.
   e. Standing Committees.
5. Committees appointed by the President:
   a. Committee of five on nomination of officers for ensuing year.
   b. Committee of three on time and place of next meeting.
   c. Auditing committee of three.
   d. Committee of three on program.
   e. Committee of three on publication.
   f. Committee of three on publicity.
6. Reading of papers and discussions of same.

   (*Note*—In the reading of papers preference shall be given to the members present.)
7. Miscellaneous business.
8. Adjournment.

ARTICLE VII

Changing the Constitution

The Constitution of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least fifteen members are present at said regular meeting.

AMERICAN FISHERIES SOCIETY
LIST OF MEMBERS

(Showing Year of Election to Membership)

HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Nicolas, Museum of Comparative Zoology, Harvard University, Cambridge, Mass.
'04 Denbigh, Lord, London, England.
'04 Kishinouye, Dr. K., Imperial University, Tokyo, Japan.
'17 Mercier, Honoré, Minister of Lands and Forests, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.
'06 Perrier, Prof. Edmond, Director, Museum of Natural History, Paris, France.

PATRONS

'14 Alaska Packers Associations, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 Bond and Goodwin, 485 California St., San Francisco, Calif.
'15 Burpee and Letson, Ltd., South Bellingham, Wash.
'15 California Barrell Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore and Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.

'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Clinch, C. G. & Co., Inc., 144 Davis St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co. (C. W. Weld, Mgr.), 301 Brannon St., San Francisco, Calif.
'15 Dodge, Sweeney & Co., 36-48 Spear St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3rd St., San Francisco, Calif.
'15 Hendry, C. J., Co., 46 Clay St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The, (W. A. Barbour, Mgr.), 443 Mission St., San Francisco, Calif.
'15 Mattlage, Chas. F., Company, 335 Greenwich St., New York, N. Y.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Nauman, C., & Co., 501-3 Sansome St., San Francisco, Calif.
'15 Pacific Hardware and Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Phillips Sheet and Tin Plate Co., Weirton, W. Va.
'15 Pope and Talbot, Foot of 3rd St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S., Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California (W. D. Rigdon, Mgr.), 50-60 Fremont St., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'12 Barnes, Ernest, Fisheries Experiment Station, Wickford, R. I.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'13 Benson, John T., 307 Newark St., Hoboken, N. J.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wisconsin.
'25 Bradford, W. A., 14 Wall St., New York, N. Y.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'03 Casselman, E. S., 508 West Washington St., Sandusky, Ohio.
'11 Cleveland, W. B., Burton, Ohio.
'00 Corliss, C. G., U. S. Bureau of Fisheries, Gloucester, Mass.
'01 Dean, Herbert D., Northville, Mich.
'00 Dunlap, Irving H., U. S. Bureau of Fisheries, Washington, D. C.
'12 Fearing, Mrs. D. B., Newport, R. I.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'10 Gardner, Mrs. Charles C., The Cliffs, Newport, R. I.
'26 Goelet, Robert W., 18 East 47th St., New York, N. Y.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Laboratory, Woods Hole, Mass.
'23 Grey, Zane, Avalon, Calif.
'28 Hall, W. A. Co., Gardiner, Mont.
'26 Haynes, W. de F., 49 Park Ave., New York, N. Y.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'23 Lloyd-Smith, Wilton, 43 Exchange Place, Care of Cotton & Franklin, New York, N. Y.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco, Calif.
'94 Meehan, W. E., 422 Dorset St., Mt. Airy, Philadelphia, Pa.
'99 Morton, W. P., 105 Sterling Ave., Providence, R. I.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205-8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3rd St., Columbus, Ohio.
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'17 Pratt, George D., 26 Broadway, New York, N. Y.
'08 Prince, Dr. E. E., Dominion Commissioner of Fisheries, Ottawa, Canada.
'10 Radcliffe, Lewis, U. S. Bureau of Fisheries, Washington, D. C.
'93 Ravenel, W. de C., U. S. National Museum, Washington, D. C.
'20 Robertson, Hon. James A., Skerryvore, Holmefield Ave., Clevely's Blackpool, England.
'05 Safford, W. H., 229 Wing St., S., Northville, Mich.
'27 Sheldon, Edward W., 46 Park Ave., New York, N. Y.

'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'01, '12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Vallette, Luciano H., 827 Rivadavia, Buenos Aires, Argentina.
'14 Vandergrift, S. H., 1728 New Hampshire Ave., Washington, D. C.
'22 Walcott, Frederic C., Norfolk, Conn.
'98 Ward, Dr. Henry B., University of Illinois, Urbana, Ill.
'13 Wisner, J. Nelson, Institute de Pesca del Uruguay, Punta del Esto, Uruguay.
'05 Wolters, Charles A., Oxford and Marvine Sts., Philadelphia, Pa.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

ACTIVE MEMBERS

'16 Adams, Dr. Charles C., State Museum, Univ. of the State of N. Y., Albany, N. Y.
'13 Adams, William C., Dept. of Conservation, Albany, N. Y.
'31 Agersborg, Dr. H. P. K., Dept. of Fisheries and Game, Concord, N. H.
'29 Ainsworth, A. L. Tuxedo Fisheries, Tuxedo Park, N. Y.
'31 Aldrich, A. D., 2879 East Archer, Tulsa, Okla.
'31 Allen, Walter M., U. S. Bureau of Fisheries, La Crosse, Wis.
'29 Allen, William Ray., Dept. of Zoology, University of Kentucky, Lexington, Ky.
'26 Alm, Dr. Gunnar, Commissioner of Fresh Water Fisheries, Lantbruksstyrelsen, Stockholm, Sweden.
'23 Amsler, Guy, Department of Fish and Game, Little Rock, Ark.
'08 Anderson, August J., Box 704, Marquette, Mich.
'24 Annin, Harry K., Spring Street, Caledonia, N. Y.
'14 Annin, Howard, Van Cortland Ave., Ossining, N. Y.
'25 Atherton, Giles, Citizens State Bank, El Dorado, Kansas.
'29 Atkinson, C. J., Fisheries Dept., Ottawa, Ont., Canada.
'01 Babcock, John P., Provincial Fisheries Department, Victoria, B. C., Canada.
'32 Baer, Harry D., % U. S. Bureau of Fisheries, Hagerman, Idaho.
'32 Bailey, G. E., Dominion Government Fish Hatchery, Twin Butte, Alt., Canada.
'32 Bailliere, Lawrence, Stoutland, Mo.
'32 Bajkov, Dr. A. B., University of Manitoba, Winnipeg, Man., Canada.
'27 Baker, Clarence, 2 South Carroll St., Madison, Wis.
'29 Baker, Dr. Davis, Insurance Bldg., Glens Falls, N. Y.
'15 Balch, Howard K., 156 West Austin Ave., Chicago, Ill.
'98 Ball, E. M., 1328 South Kingshighway, St. Louis, Mo.
'23 Bangham, Dr. Ralph V., Wooster College, Wooster, Ohio.
'20 Barbour, F. K., Linen Thread Co., 200 Hudson St., New York, N. Y.
'05 Barbour, Prof. Thomas, Museum of Comparative Zoology, Cambridge, Mass.
'26 Barnes, J. Sanford, 52 Vanderbilt Ave., New York, N. Y.
'28 Beakbane, Alfred Bernard, 31 Thompson Ave., Glens Falls, N. Y.

'00 Beeman, Henry W., New Preston, Conn.
'28 Bell, F. Howard, International Fisheries Commission, University of Washington, Seattle, Wash.
'18 Bellisle, J. A., Inspector General of Fisheries and Game, Quebec, Canada.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'25 Bengard, John P., Valley Ranch, New Mexico.
'13 Berg, George J., Indiana Fish Commission, Indianapolis, Ind.
'27 Biddle, Spencer, R. F. D. No. 1, Vancouver, Wash.
'27 Birdseye, Clarence, General Seafoods Corporation, Gloucester, Mass.
'28 Bishop, M. S., R. F. D. No. 2, Iroquois Trout Hatchery, Glens Falls, N. Y.
'24 Bitzer, Ralph, Montague, Mass.
'24 Blanchard, Charles, State Fish Hatchery, Unionville, Conn.
'25 Blankenship, Dr. E. L. Crystal Springs Trout Farm, Cassville, Mo.
'32 Blosz, John, Lake Park, Ga.
'32 Bogie, Robert R., 6740 Fourth Ave., Brooklyn, N. Y.
'26 Borcea, Dr. Jean, Univ. of Jassy, Jassy, Roumania.
'30 Borger, Garrison, Brookhaven, N. Y.
'25 Borger, Samuel I., Brookhaven, N. Y.
'30 Bosdeck, Ed., State Fish Hatchery, Route 11, Defiance, Ohio.
'25 Bottler, P. G., State Fish Hatchery, Emigrant, Montana.
'00 Bower, Ward T., U. S., Bureau of Fisheries, Washington, D. C.
'30 Bowling, T. C., Pryor, Okla.
'30 Branion, Hugh D., Dept. of Biochemistry, University of Toronto, Toronto, Canada.
'20 Breder, C. M., Jr., New York Aquarium, New York, N. Y.
'26 Brenard, Thomas L., % Martin Fish Co., Atchafalaya, La.
'28 Brittain, William H., New Amsterdam, 14th and Fairmont Sts., Washington, D. C.
'16 Brown, Dell., U. S. Bureau of Fisheries, Lonoke, Ark.
'26 Brown, George E., Graybar Electric Co., Inc., 4508 York Ave., S., Minneapolis, Minn.
'30 Brown, James, Commissioner of Fish and Game, Montpelier, Vt.
'32 Brown, Merrill W., Box 956, Stanford University, Calif.
'28 Brunelli, Gustav, Director del Laboratorio Centrale d'Idrobiologia, Piazza Borghese, 91, Rome, Italy.
'20 Buller, C. R., Pleasant Mount, Wayne County, Pa.
'29 Burke, Dr. Edgar, Jersey City Hospital, Jersey City, N. J.
'17 Burkhart, Joe, Big Rock Creek Trout Club, St. Croix Falls, Wis.
'31 Burr, J. G., Game, Fish and Oyster Commission, Austin, Tex.
'28 Butler, Edward C., Box 125, Allston Station, Boston, Mass.
'30 Butler, George Edward, Winnipegosia, Man., Canada.
'27 Byers, A. F., 1226 University St., Montreal, Que., Canada.
'27 Cable, Louella E., U. S. Bureau of Fisheries, Washington, D. C.
'32 Carl, Elmer B., 24 Broadway, Hagerstown, Md.
'23 Catt, James, District Inspector of Hatcheries, Customs House, St. John, N. B., Canada.

'07 Catte, Eugene, Catte Fish Hatchery, Langdon, Kansas.
'18 Chamberlain, Thomas Knight, 7 Willis Ave., Columbia, Mo.
'32 Chrassin, J. P., Margaree Harbor, N. S., Canada.
'29 Chute, Walter H., Director, John G. Shedd Aquarium, Grant Park, Chicago, Ill.
'32 Clark, Arthur L., State Capitol, Hartford, Conn.
'21 Clemens, Dr. Wilbert A., Pacific Biological Station, Nanaimo, B. C., Canada.
'00 Cobb, Eben W., R. F. D., Farmington, Conn.
'29 Cokeley, H. A., Crawford, Neb.
'04 Coker, Dr. Robert E., Univ. of North Carolina, Chapel Hill, N. C.
'26 Comee, Joseph F., People's Gas Bldg., Chicago, Ill.
'28 Cook, A. B., Jr., Field Supt. of Hatcheries, Ionia, Mich.
'22 Cook, Frank, Laramie State Fish Hatchery, Laramie, Wyo.
'17 Cook, Ward A., U. S. Bureau of Fisheries, Duluth, Minn.
'24 Coolidge, Charles A., 122 Ames Building, Boston, Mass.
'32 Cooper, K. N., Auburndale Gold Fish Co., 1449 Madison St., Chicago, Ill.
'32 Corder, H. G., Anderson Lake Hatchery, Kildonan P. O., Vancouver Island, B. C., Canada.
'31 Cotton, Maj. Ray E., Secy., Dept. of Conservation, Lansing, Mich.
'32 Cowden, Sumner M., Conservation Dept., Albany, N. Y.
'30 Craig, Charles, Dept. of Conservation, Lansing, Mich.
'13 Crandall, A. J., Ashaway Line & Twine Mfg. Co., Ashaway, R. I.
'32 Crawford, H. C., Nelson Hatchery, Nelson, B. C., Canada.
'31 Crosby, Caroline M., 2105 First Ave., South, Minneapolis, Minn.
'28 Crosby, Col. W. W., Box 685, Coronado, Cal.
'30 Crowell, Mary, Shortsville, N. Y.
'08 Culler, C. F., U. S. Bureau of Fisheries, La Crosse, Wis.
'28 Cumings, Ed., % Cumings Brothers, 901 S. Saginaw St., Flint, Mich.
'12 Danglade, Ernest, Vevay, Ind.
'31 Dauenhauer, J. B., Jr., Courthouse Bldg., New Orleans, La.
'06 Davies, David, U. S. Fisheries Station, Put-in-Bay, Ohio.
'28 Davis, Hosea L., Fisheries Station, Mammoth Springs, Ark.
'23 Davis, Dr. H. S., U. S. Bureau of Fisheries, Washington, D. C.
'26 Day, Harry V., 510 Park Ave., New York, N. Y.
'31 Deake, Standish, Div. Fish and Game, 20 Somerset St., Boston, Mass.
'27 DeBoer, Marston J., Dept. of Conservation, Lansing, Mich.
'25 De Cozen, Alfred, 1226 Broad St., Newark, N. J.
'28 De Forest, Byron, P. O. Box 971, Great Falls, Mont.
'30 Deibler, O. M., Commissioner of Fisheries, Bd. of Fish Cmrs., Harrisburg, Pa.
'24 Dence, Wilford A., New York State College of Forestry, Syracuse, N. Y.
'19 Denmead, Talbott, 2830 St. Paul St., Baltimore, Md.
'23 Dennig, Louis E., 3817 Choteau, St. Louis, Mo.
'08 Detweiler, John Y., Honorary Pres., Florida Fish Commission, New Smyrna, Fla.

'30 Detwiler, John D., University of Western Ontario, London, Ont., Can.
'30 Devlin, Marie Blanche, Parliament Bldgs., Colonization Dept., Quebec, Canada.
'99 Dinsmore, A. H., U. S. Bureau of Fisheries, St. Johnsbury, Vt.
'32 Domogalla, Dr. Bernhard, 803 State St., Madison, Wis.
'27 Dorn, C. G., 50 Jackson Ave., Bradford, Pa.
'28 Dunlop, Henry A., International Fisheries Com., University of Washington, Seattle, Wash.
'32 Dwyer, J. N., 371 St. Joseph Blvd., W., Montreal, Canada.
'24 Earle, Swepson, Conservation Dept., 516 Munsey Bldg., Baltimore, Md.
'27 Eaton, Dr. E. H., 678 Main St., Geneva, N. Y.
'32 Eaton, R. H., Pitt Lake Hatchery, Alvin, B. C., Canada.
'32 Eddy, Samuel, Zoological Dept., Univ. of Minnesota, Minneapolis, Minn.
'26 Einarsen, Arthur S., Box 384, Seattle, Wash.
'31 Eisenlohr, George M., U. S. Fisheries Station, La Crosse, Wis.
'31 Eddy, Samuel, Zoology Dept., University of Minnesota, Minneapolis, Minn.
'32 Ekers, L. A., 1455 Drummond St., Montreal, Canada.
'31 Emberson, G. F., De Soto, Wis.
'13 Embody, Dr. George C., Triphammer Road, Ithaca, N. Y.
'21 Emerick, Walter G., R. F. D. 1, Iron Kettle Trout Hatchery, Watervliet, N. Y.
'26 Emmons, H. Nelson, Marion, Mass.
'32 Epps, E. V., Vedder Crossing P. O., B. C., Canada.
'17 Erickson, C. J., P. O. Box 1446, Boston 2, Mass.
'32 Eschmeyer, R. William, University Museums, Ann Arbor, Mich.
'04 Everman, J. W., Supervisor of Public Utilities, Dallas, Texas.
'29 Farley, John L., 450 McAllister St., Fish and Game Commission, San Francisco, Calif.
'32 Farrell, Michael A., Dept. of Bacteriology, Yale Univ., New Haven, Conn.
'28 Fearnow, Theodore C., State Fish Hatchery, Ridge, W. Va.
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